Exploring Virtual Reality as a Platform for Early-Stage Design for Human Augmentation Technologies

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(a) JumpiFlumpi

(b) PortalGhost

(c) GuidingLight

Figure 1: Screenshots of the prototypes developed by the course participants showcasing the Virtual Environments

ABSTRACT

Human Augmentation Technologies (HATs) aim to enhance human capabilities and transform our interactions with the environment and each other. However, testing and prototyping HATs is complex and challenging. This study explores using Virtual Reality (VR) as a developmental platform for HATs within an educational framework. Through a semester-long course, students designed virtual augmentations within a VR environment. We showcase three resulting VR applications and interviewed four students about their experiences ideating and implementing virtual augmentations. Our results highlight the need for a set of guidelines for virtual augmentations based on best practices. Moreover, participants mostly opted for physical augmentations, revealing limitations of VR, i.e., simulator sickness and absence of haptic feedback. Despite challenges, the virtual augmentations received positive feedback, offering stimulating and immersive experiences. This highlights the potential of virtual augmentations as a driver for engaging experiences in VR and as a valuable tool for early HAT development and research.

CCS CONCEPTS

• **Human-centered computing → Activity centered design**; *Scenario-based design.*

KEYWORDS

Virtual Reality, Human Augmentation, Virtual Augmentation, Haptics

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1 TOWARDS VIRTUAL REALITY HUMAN AUGMENTATION

Human augmentation technologies (HATs) improve human performance to a level that would not be possible otherwise [1, 2]. These technologies could change how people interact with their surroundings and execute tasks that require specific physical, mental, or sensory skills [7, 9].However, the inherent complexity and functional diversity of HATs pose significant challenges in their prototyping, development, and testing [10, 11].

Recent research has explored the potential of Virtual Reality (VR) as a platform to prototype HATs by leveraging the concept of "superpowers" within VR [8]. This approach turns VR's inherent limitations in replicating the physical world into an advantage by shifting the focus from replicating reality to creating experiences otherwise impossible [6]. Thus, by intentionally exceeding these effects, VR-based superpowers can explore functionalities that are currently unrealizable in the real world, serving as inspiration for future HAT development.

Thus, in this work, we leverage these frameworks to explore the ideation and development process within a VR educational setting. **Methods and Procedure:** As part of a university VR course, we conducted a week-long exercise to prototype Human Augmentation (HA) in VR. The course included 19 master's and bachelor's students in media informatics and computer science.Participants developed a VR game using virtual augmentation. Prototypes incorporated Electromyography (EMG) for input, multiplayer functionality, and non-verbal communication within VR. The course introduced virtual augmentation through a lecture based on Raisamo et al. [7]. Brainstorming sessions encouraged creative HA concepts, and students followed an iterative process to refine their group prototypes. Finally, a week was dedicated to finalizing and presenting the applications. Then, we invited participants to voluntarily join an interview about their experience developing the VR game. We conducted semi-structured interviews with four participants (2 female, 2 male, aged 25-29) from three different project groups. Two were master's students in Human-Computer Interaction, one was a master's student in IT, and one was a bachelor's student in computer science. Two had prior experience developing VR applications; the other two had none. In the interviews, we asked participants about their game, its key features, and the ideation process. Next, we covered the development process. Finally, participants discussed virtual and human augmentation, sharing potentials and challenges from their experience. We concluded by inviting further thoughts or questions. After obtaining consent, we audio-recorded and transcribed the interviews for analysis. We then conducted a content analysis following Mayring [4]. The first three authors independently coded the data and collated the results.

2 RESULTS

The course produced three HAT prototypes; game mechanics and EMG functionalities are described below:

Jumping Augmentation: JumpiFlumpi is a game that blends physical activity with competitive gameplay. Players compete for the highest score by jumping in a virtual environment. *Mechanics:* Players squat to jump in the game, with squat duration determining jump height. *EMG Functionality:* Squatting serves as the main input (see Figure 1 left).

Object Manipulation: PortalGhost is a team-based puzzle game set in a laboratory. One player controls a human character in VR, while the other, a ghostly entity, is controlled via desktop PC. *Mechanics:* The ghost can pass through walls, create portals, and share its vision with the VR player, enabling interaction with distant objects. *EMG Functionality:* EMG sensors on the biceps and forearm detect muscle contractions to control telekinesis. Biceps contractions pull objects closer, while arm extension pushes them away (see Figure 1 center).

Super Strength: GuidingLight is a two-player game where one player, in VR, fights zombies, and the other, in the real world, enhances the VR player's abilities using EMG. *Mechanics:* The VR player fights zombies with hand controllers, while the supporter uses EMG to charge abilities. *EMG Functionality:* EMG sensors detect muscle contractions, boosting the VR player's power, slowdown durations, and teleportation range (see Figure 1 right).

Ideation and Implementation of Virtual Augmentations: All participants described a typical group ideation process: they performed brainstorming sessions to collect quick ideas and then discussed and selected together. Coming up with initial ideas for virtual augmentations was generally regarded as easy (P3, P4). However, because they had little experience with virtual augmentation, they could not yet imagine how easily the ideas could be realized and what the experience would be like: *"[...] in our fantasy, I think it was easy to imagine what it [the virtual augmentation] should look like. I think it wasn't 100 percent clear at the start what we could get done in that time, that is fun. [...] I mean, that was the hard part, I would say."* (P4).

All participants describe different starting and focus points during their ideation. While P2 mentioned that their group started by brainstorming ideas for possible virtual augmentations very openly, P4 described that their group initially settled on a game mechanic and only proceeded to ideate and select augmentations afterward. In contrast, P3 mentioned that their group took the required input method as the basis for their ideation. When deciding on their virtual augmentations, the groups attempted to implement abilities that would go well beyond what humans can achieve in the real world, even by training. Ideally, the virtual augmentations would go even further and represent abilities that are impossible or too dangerous in the real world, even with considerable expenditure (e.g., portals or super jumps).

We found two layers in the groups' intentions when ideating and developing the virtual augmentations. First, multiple participants (P1, P4) explained that they aimed to make the augmented abilities as intuitive as possible and enable players to feel like the ability is really a part of their body. The virtual augmentations should be understandable, easy, and fun to use. Second, participants outlined the experience their groups intended to create for players. Key motives all participants mentioned were to create stimulating experiences that allow players to explore new abilities and feel empowered or unconstrained by the new virtual abilities. For instance, P1 and their group implemented an ability through which flexing the players' muscles would charge a strong punching ability and make the lights in the virtual environment flare up. This was meant to make the player feel powerful but also encourage exploration: *"I think it [the virtual augmentation] also was a motivation to just like try around because a different hand would make a different light and a different ability. And I think that also like motivated the player to just, like, play."* (P1) While the first layer can be considered the usability for virtual augmentation to make sure that the experience is smooth and working well, the second layer describes what should make the experience positive and valuable for the players. As this was the first time the participants engaged with virtual augmentation, it is unsurprising that the described intended experiences revolve around being new and surprising for players. In the future, we believe that other motives are possible as well.

Virtual and Human Augmentation: Participants found working with and experiencing virtual augmentation positive. Some (P3, P4) noted that wielding superpowers or impossible abilities was fun. Additionally, several participants (P1, P2) felt these abilities could spark interest and motivate VR use. P3 explained that they felt that well-implemented virtual augmentations could help make a VR experience more immersive and realistic: *"I think there are advantages of it because it just feels more realistic. Also the way you can interact [...] feels more natural [...]. So I think it's more, yeah, more immersive."* Moreover, abilities in the virtual world are not fixed and can be tailored to users with different requirements. P2 mentioned how they see the potential of this design approach when designing for users with disabilities: *"It is also one method to let [users with] disabilities play the game."* In some cases, the groups specifically focused on creating an experience in which players with different (virtual) abilities cooperate to reach the goal.

Participants noted drawbacks of virtual augmentation. Body movement-based augmentation can cause physical exhaustion and limit user accessibility (P1, P4). Augmentations affecting movement or physical abilities often risk causing simulator sickness (P3, P4). Increased force is particularly hard to implement due to the lack of resistance in VR, requiring precise audio-visual feedback for a satisfying experience (P1).

In the interviews, the participants reflected on the relationship between human augmentation in the real world and virtual augmentations. Looking at the virtual augmentations from the games, most are fully or almost impossible to transfer into real life and would cause serious safety concerns (P2, P4). Even when it is possible to transfer virtual augmentations to the real world, the technological effort required and the danger associated with abilities like jumping seem too large to make it worth it (P4). In VR, more or different abilities are possible (e.g., teleportation) (P2, P3) and the virtual environment is a safe space to explore enhanced abilities in the absence of many security concerns. However, the virtual space also comes with some drawbacks, as the lack of physical feedback and resistance make it harder to implement physical augmentations believably, and the augmented movement quickly causes simulator sickness (P3, P4) or requires complicated technological setups (e.g., for natural movement).

3 DISCUSSION AND FUTURE WORK

While generating initial ideas was seen as straightforward, specific challenges arose. Since focusing on virtual augmentations is not widely established, typical practices like using published examples for inspiration, common in VR development, are unavailable [3]. There is little formal knowledge on creating a good user experience for virtual augmentations. Participants emphasized the need to ensure augmented interactions work well, are easily understood, and feel intuitive (usability). Additionally, positive experiences should stimulate exploration and new abilities. However, there is a risk that the novelty of virtual augmentations makes them temporarily enjoyable. To create lasting positive experiences, designers should focus on making virtual abilities satisfying to use (inducing flow) or offering new perspectives and insights, particularly in non-game applications, relevant to users' goals.

In the practical exercise, groups were free to choose the type of HATs to develop. Most focused on augmentations affecting physical or movement abilities. Although "superpowers" often come to mind, they are hard to achieve with current VR technology. While VR enables physical and spatial interactions, new forms of movement risk causing simulator sickness or requiring advanced equipment like treadmills. Augmented force can feel hollow, as current VR systems primarily provide visual feedback—lifting a heavy object feels the same as lifting a light one. VR is traditionally better suited to audio-visual illusions. Future virtual augmentations may focus more on enhancing perception than action, or through systems that incorporate haptic feedback. While we acknowledge the inherently small sample size of this study, it is important to emphasize that our focus was on exploratory qualitative work. Our primary interest lies in the existence of phenomena rather than their incidence. Therefore the subjective insights provided by our participants serve as a valuable starting point, offering rich insights that could be further developed in future research. Additionally, it is important to note that our primary focus was on the prototyping process itself, and as such, we did not conduct a user evaluation of the applications. Future studies could build upon our findings by incorporating larger sample sizes and user-testing phases to further validate and expand on the insights generated here. Beyond this, virtual augmentation has the potential to enhance user experience in VR when implemented effectively. Previous studies have highlighted its value in VR design (e.g., [8]), positive VR experiences [5, 6].

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