Virtual Dance Mirror: A Functional Approach to Avatar Representation through Movement in Immersive VR

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ABSTRACT

Immersive Virtual Reality (VR) technologies offer new possibilities for studying embodied interaction with different sets of constraints and affordances for action-taking while using one's physical body. In this study, we designed and prototyped a VR dance experience, Virtual Dance Mirror, where a dancer's bodily movements are reflected on a 3D avatar model using a motion-capture suit. We investigated the novel possibilities for avatar design based on the expression of movements available for dancers in VR environment. After a preliminary briefing session, we conducted a user-study with five dancers with semi-structured interviews. Our findings support HCI literature on virtual body design to facilitate collaboration and non-verbal communication between VR users.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Collaborative interaction**; *Empirical studies in interaction design.*

KEYWORDS

Embodiment, avatar representation, dance, movement, virtual reality

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1 INTRODUCTION

Different than screen-based virtual environments, Virtual Reality (VR) experiences with head-mounted displays (HMDs) are marked by their high immersion context which provides users with deeper mental and bodily involvement with the world [15]. High immersion not only affects the level of involvement, but also the possibilities for action available to users. The way users navigate and manipulate the virtual world can influence how different users communicate and collaborate with one another [5]. Investigating human cognition and behavior in an immersive setting that is outside of the available modes of interaction in the physical world benefits the design and development of future VR experiences. In VR, users are not only situated in an immersive space, but they also often embody a virtual body which influences how users relate to themselves and others [12]. Appearance and behavior of the virtual body can be found in different degrees of realism (and abstraction) in these platforms which opens new possibilities and limits for bodily interaction [6].

There are two approaches to avatar embodiment in HCI research, one that aims for a realistic human body and behavior and the other that explores alternative, surreal, abstract representations. The former requires a high-fidelity simulation of how the body looks and behave in real-life to maintain bodily interaction cues intact (such as posture). The latter is more interested in investigating alternative embodiment and implications for VR experiences [8]. This study focuses on the second approach and alternative embodied experiences that can create novel communication dynamics among VR users, particularly in settings where bodily coordination is required to complete a task. We designed a VR prototype, Virtual Dance Mirror,

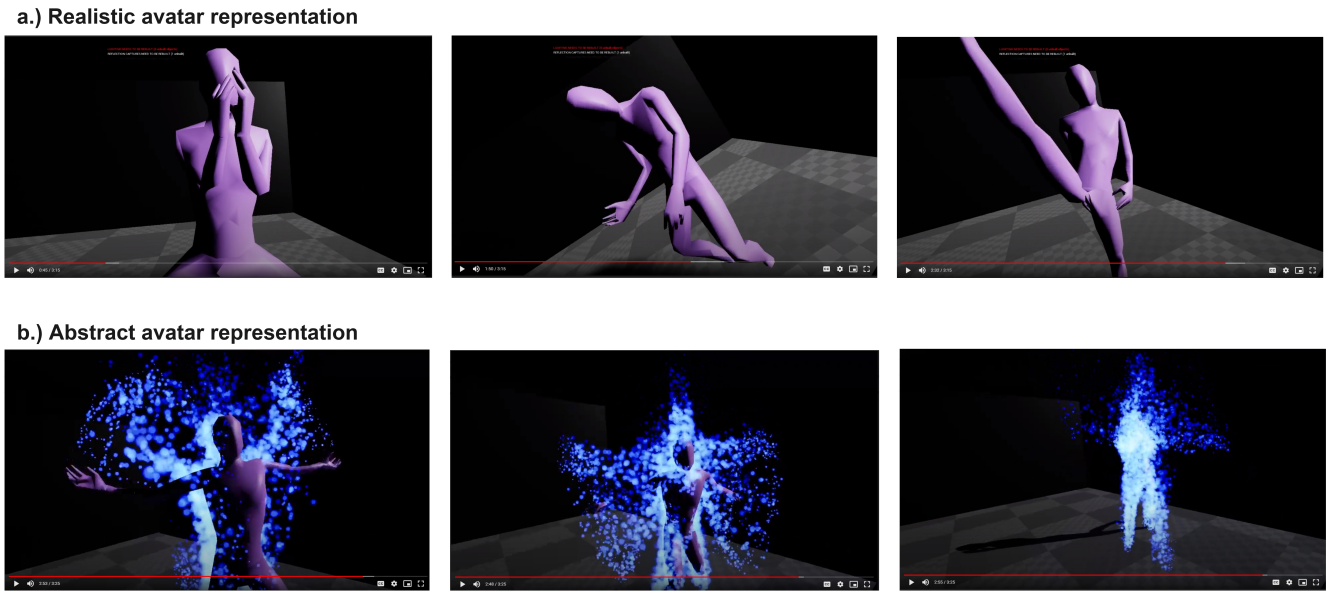

Figure 1: Scenes from the the prototype depicting (a) realistic and (b) abstract avatar body representations.

which reflects two types of body representations: realistic and abstract. We asked five professional dancers to perform a short dance performance using our prototype and reflect on their experiences in different embodiment settings. In this case-study, participants reflected on how different avatar representations affected their movement and own-body perception. The video-outputs of these performances were evaluated in an elicitation interview with a think-aloud protocol.

2 BACKGROUND

Recent HCI research observes a "third-wave" shift in bringing in dance performances for creative experience design, connecting what we learn from the interlinks between dance and technology on the topic of embodied interaction [4]. In this new interdisciplinary integration, HCI not only offers novel design solutions for interactive dance performances, it also benefits from the dance literature and practice in terms of avatar and movement design [10].

Technology offers a new relationship to the body ("subjective sense of body") and a new kind of body awareness [3]. In the context of dance performance, embodiment means being aware of this relationship to the body [3]. To illustrate this, a recent study of an immersive dance performance [1], Skin Awareness, experiments with shifting the limits of body territory and surrounding space through applying the concept of embodied perception "using immersive projection and light media" (p. 3). By changing the embodied perception of body and space, they explored new action capabilities of the body that went beyond its usual capacity (p. 4).

Another study observes that temporal representation of the movements of the virtual body can influence the way the physical body is perceived [7]. Altering the visual perception of one's body through asynchronous spatio-temporal feedback is shown to change the feeling of bodily sensations. A full-body motion-capture system is developed to generate predicted past and future body movements of the dancer whose body is projected in a slightly deformed state with a HMD. A body image generated at 25-100ms in the future elicited a sensation of a lighter weight. In another study, the temporal representation of bodily movements not only affect one's own relationship with the body and surrounding space, but also how one relates to and interacts with others' body [12]. They show that synchronous movements help create social closeness among individuals.

XR is not only relevant for creating novel dance performances, it can also help using dance in other contexts such as motor learning [14]. In one work, a pedagogical interactive installation called Double Skin/Double Mind (DS/DM) is designed for the analysis and visualization of movement qualities as a learning tool in dance training [2]. In another study, a whole-body interaction interface is built to represent different visualization of movement through a real-time motion capture and 3D models to aid in dance learning. Users can experiment with different avatars from multiple point of views with different movement visualizations projected onto a 2D screen [13]. Another immersive environment was created through CAVE fused with a motion capture technology (MS Kinect) for ballet students to practice dance movements instructed by a virtual instructor. The students can review their own performance from different perspectives and improve their dance skills [9].

3 METHODOLOGY

Design and prototyping process included a preliminary focus group discussion with two dancers, a choreographer, a film director and a VR developer. With this brief, we designed a VR prototype and conducted a user-study with 5 dancers followed by an interview with a think-aloud protocol with each.

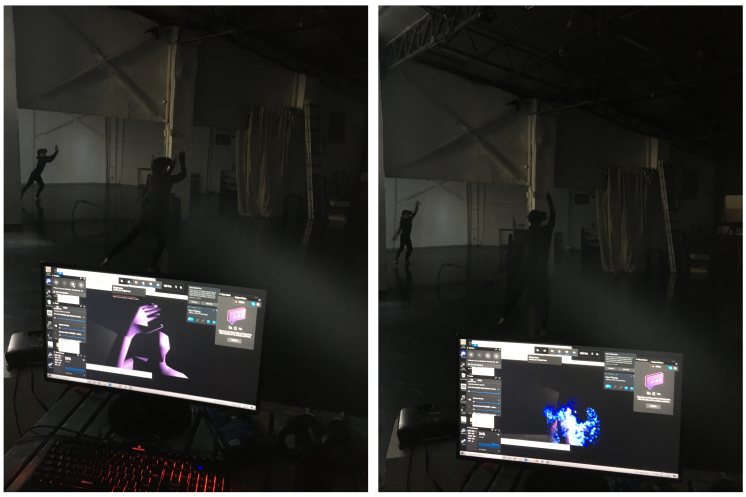

Figure 2: A sequence from the user study

We built a VR application using Unreal, to be used in HTC Vive. To reflect the dancer in VR, we used the Rokoko motion capture suit and streamed its data to the Unreal application in real-time. The environment was a black room, as we wanted the focus to be on the avatar movements and there were two different avatars, one was a simple human body without facial features) and the other one was the same avatar with a particle system animation overlaid - giving it a fire-like look and making it more abstract and surrealistic (Figure 1). The app was setup so that the participants could see the avatars animated with their own movement in front of themselves. They were free to move around.

We asked participants to perform an improvisation wearing the motion-capture suit and headsets. First, they saw a realistic virtual body which reflected the movements as visually clear and precise as possible. We recorded a 3 minute video-capture of the dancers' view in VR for each abstract and realistic body representation (Figure 2).

4 FINDINGS AND DISCUSSION

In the preliminary briefing session prior to the development of our prototype, Virtual Dance Mirror, dancers worked with the 2D representations of their body projected onto the Unreal scene using a motion-capture suit. Dancers explored the virtual performance capabilities through trying out techniques and learning from errors. This process is explained by dancers as a process of looking for the rules of the world, in that they explored the movement capabilities in virtual reality by trial and error:

- Dancers decided on a set of movements that fit well to the VR environment and tracking capabilities. For instance, using less floor movements within a limited spatial area provides a better simulation of the movements of the physical body.
- Using abstract visual cues for temporal representation of movement augments the virtual performance. As most of the somatosensory or kinesthetic cues are dissipated in the virtual avatar representations, augmenting the virtual body through other interaction cues that give a pattern and tempo to the movement can aid dancers with missing information coming from the physical body.

During the elicitation interviews of the user-study, dancers reflected that avatar design itself changes the movement of the virtual and physical body. One participant (P1) explained that *"abstract representation brings a new proposition to action"*, in that, it postulates an alternative motor model for embodied interaction. This is in line with the research on embodiment that suggests that if the physical body does not match with the virtual body, we adjust our behavior to match the input [11]. For instance, when comparing their performances in two types of representations, three dancers explained that they moved their physical body in a more sudden and gross manner to make use of abstract visual cues to express the pattern and tempo for movement. Two dancers explained that they used abstract cues to leave a trace in the virtual space, enabling them to see how their body movements make an influence on the environment. One dancer referred to this as *"filling the space with movement"* (P3). All five participants conveyed that abstraction helped their body to express movements impossible with their physical bodies.

Dancers also suggested that they focused on their virtual body differently in realistic vs abstract avatar representations, which influenced how they perceived their own body. During the study, participants viewed their virtual bodies from a third person perspective mirror view *"using the headset as a camera"* (P4). When they watched the 2D output of their performances, they compared the way they used their visual field as a camera view of the virtual body. Four participants explained that abstract representations made them look at the virtual mirror in a more full-body, holistic manner, from afar, with sudden perspective shifts whereas the realistic representation made them focus more selectively on the body parts and its movements.

Dancers expressed that when they embodied an abstract representation, the precision of the movements as reflected in the virtual mirror was broken which made them rely on the somatosensory input less, and visual output more. This, not only affected the way

they conceive and perform movement, but also their own-body perception. All participants suggested they felt alienated from their self-executed movements, connoting a sense of engaging in a duet rather than a solo performance. Dancers pointed out the lack of somatosensory input to convey a sense of self shaped the interaction as a reciprocal action-taking between the physical and virtual body. Participants also suggested that VR can be a useful tool for collaboration among different dancers and choreographers by enabling them to embody each other's perspectives.

There are two main implications of the study; (1) Looking at how dancers describe their experiences in virtual mirror prototype, an abstract representation of the human body can elicit a wider range of movement capabilities rather than a realistic representation which can enhance the interaction between agent and the environment and between others. (2) The second implication is that this study offers a new approach to avatar design and body representation in the embodied interaction setting of immersive VR based on the vocabulary of movements in performance arts. Low level abstract representations rather than high quality realistic ques can be a better way to approach avatar design, particularly in the contexts of collaborative work that require coordination of movements and bodily interaction such as dance. Future work should focus on the more collaborative context of interaction between multiple dancers, exploring the effects of different avatar representations on the joint performance and communication.

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REFERENCES

[1] Sarah Fdili Alaoui. 2019. Making an interactive dance piece: Tensions in integrating technology in art. *DIS 2019 - Proceedings of the 2019 ACM Designing Interactive Systems Conference* (jun 2019), 1195–1208. https://doi.org/10.1145/3322276.3322289

[2] Sarah Fdili Alaoui, Frederic Bevilacqua, and Christian Jacquemin. 2015. Interactive Visuals as Metaphors for Dance Movement Qualities. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 5, 3 (sep 2015). https://doi.org/10.1145/2738219

[3] Yoav Bergner, Shiri Mund, Ofer Chen, and Willie Payne. 2019. First steps in dance data science: Educational design. *ACM International Conference Proceeding Series* (oct 2019). https://doi.org/10.1145/3347122.3347137

[4] Miguel Bruns, Stijn Ossevoort, and Marianne Graves Petersen. 2021. Expressivity in interaction: A framework for design. *Conference on Human Factors in Computing Systems - Proceedings* (may 2021). https://doi.org/10.1145/3411764.3445231

[5] Jennifer Fromm, Milad Mirbabaie, and Stefan Stieglitz. 2020. The effects of virtual reality affordances and constraints on negative group effects during brainstorming sessions. In *Proceedings of the 15th International Conference on Business Information Systems 2020 "Developments, Opportunities and Challenges of Digitization", WIRTSCHAFTSINFORMATIK 2020.* https://doi.org/10.30844/wi_2020_k3

[6] Simon Gunkel, Hans Stokking, Martin Prins, Omar Niamut, Ernestasia Siahaan, and Pablo Cesar. 2018. Experiencing virtual reality together: Social VR use case study. *TVX 2018 - Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video* (jun 2018), 233–238. https://doi.org/10.1145/3210825.3213566

[7] Shunichi Kasahara, Keina Konno, Richi Owaki, Tsubasa Nishi, Akiko Takeshita, Takayuki Ito, Shoko Kasuga, and Junichi Ushiba. 2017. Malleable embodiment: Changing sense of embodiment by spatial-temporal deformation of virtual human body. *Conference on Human Factors in Computing Systems - Proceedings* 2017-May (2017), 6438–6448. https://doi.org/10.1145/3025453.3025962

[8] Andrey Krekhov, Sebastian Cmentowski, and Jens Kruger. 2019. The illusion of animal body ownership and its potential for virtual reality games. *IEEE Conference on Computatonal Intelligence and Games, CIG* 2019-August (aug 2019). https://doi.org/10.1109/CIG.2019.8848005 arXiv:1907.05220

[9] Matthew Kyan, Guoyu Sun, Haiyan Li, Ling Zhong, Paisarn Muneesawang, Nan Dong, Bruce Elder, and Ling Guan. 2015. An Approach to Ballet Dance Training through MS Kinect and Visualization in a CAVE Virtual Reality Environment. *ACM Transactions on Intelligent Systems and Technology (TIST)* 6, 2 (mar 2015). https://doi.org/10.1145/2735951

[10] James Leach and Scott deLahunta. 2017. Dance Becoming Knowledge: Designing a Digital "Body". *Leonardo* 50, 5 (10 2017), 461–467. https://doi.org/10.1162/LEON_a_01074 arXiv:https://direct.mit.edu/leon/article-pdf/50/5/461/1577753/leon_a_01074.pdf

[11] Antonella Maselli and Mel Slater. 2013. The building blocks of the full body ownership illusion. *Frontiers in Human Neuroscience* 7, March (2013), 1–15. https://doi.org/10.3389/fnhum.2013.00083

[12] B. Tarr, M. Slater, and E. Cohen. 2018. Synchrony and social connection in immersive Virtual Reality. *Scientific Reports 2018 8:1* 8, 1 (feb 2018), 1–8. https://doi.org/10.1038/s41598-018-21765-4

[13] Georgios Tsampounaris, Katerina El Raheb, Vivi Katifori, and Yannis Ioannidis. 2016. Exploring visualizations in real-time motion capture for dance education. *ACM International Conference Proceeding Series* (nov 2016). https://doi.org/10.1145/3003733.3003811

[14] Tumay Tunur, Sean W. Hauze, James P. Frazee, and Paul T. Stuhr. 2021. XR-Immersive Labs Improve Student Motivation to Learn Kinesiology. *Frontiers in Virtual Reality* 2 (2021). https://doi.org/10.3389/frvir.2021.625379

[15] Miao Wang, Xu Quan Lyu, Yi Jun Li, and Fang Lue Zhang. 2020. VR content creation and exploration with deep learning: A survey. , 3–28 pages. https://doi.org/10.1007/s41095-020-0162-z