Department of Electrical, Computer, and Software Engineering

Part IV Research Project

Final Report

Project Number: 62

Exploring Embodiment in Immersive XR

Name: Hazel Williams

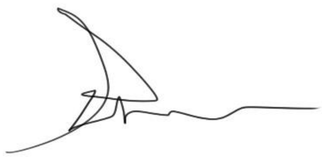
Project Partner: Eva-Rae McLean

Supervisor: Danielle Lottridge

15/10/2021

Declaration of Originality

This report is my own unaided work and was not copied from nor written in collaboration with any other person.



Name: Hazel Williams

ABSTRACT

The global pandemic has necessitated a transition to digital spaces. However, for dance this shift is complex due to the field's heavy reliance on the physical body's experience and movement. Dance provides a novel viewpoint to study sensory feedback in VR, as dancers' unique requirements may lead to new techniques unfound from a generic perspective. By identifying meaningful aspects of VR for dance, we can also support the development of effective digital dance tools. This report details the iterative process undertaken to identify compelling aspects of VR feedback for a dance context. Through a series of workshops, we identified key findings to inform the design of our final share-out. We created multiple VR experiences that linked motion captured movement to visual and audio feedback within the scene. Dancers were compelled by our particle representation as well by having sound as feedback for movement. Additionally, we identified barriers to compelling VR feedback in the form of terminology choices and movement style discrepancies. These findings will support further iteration towards a VR tool that is effective for dance.

Table of Contents

Table of Figures

1 Introduction

Social distancing and lockdowns have necessitated a transition to digital spaces for many fields. Virtual reality (VR) gives us the exciting opportunity to push the boundaries of reality and create unique experiences for users. However, the transition to VR for dance is a complex shift as it has always been an embodied art form. What happens to a dancer's sense of their body when they transition into a virtual environment?

Dance provides a novel viewpoint to study sensory feedback in VR. There are inherent challenges with integrating dance and VR due to the field's heavy reliance on the physical body's experience and movement. Dancers' unique requirements may lead to new immersive techniques unfound from a generic perspective. By identifying meaningful aspects of VR for dance, we can also support the development of effective digital dance tools.

This report details the iterative process undertaken to identify compelling aspects of VR feedback for a dance context.

1.1 Research Intent

Initially this project focused on finding what aspects of VR are compelling to embodiment specifically. However, due to lockdown, workshops with dancers in VR became infeasible. Resultingly, our research pivoted to asking what people's experiences are of various types of VR feedback relative to movement in the context of dance. This allowed us to continue to gather meaningful results with the aim of iteratively developing a compelling VR experience that elicits embodied dance movement.

In our final share-out, participants experienced multiple VR prototypes that demonstrated different kinds of VR feedback. These prototype designs were based on observations and findings from workshops.

1.2 Division of Work

Both project partners contributed equally. Work was evenly divided at each stage of the project. For the final prototypes, the partner who had access to a VR headset worked on the scenes requiring controller interaction while the other worked on the scenes that could be done without a headset.

2 Existing Research

2.1 Body Representation In VR

2.1.1 Virtual Avatars and Dance

Choreomorphy explores the impact seeing one's own body as different virtual avatars has on dance improvisation [1]. They show that after changing visual avatar aspects, some dancers alter their movement to reflect the characteristics of the modified avatar.

2.1.2 Virtual Avatars and Embodiment Research

Studies frequently assume that to produce embodiment a virtual avatar is needed for the user to project upon. However, studies quoted to justify this assumption only shallowly investigate the potential for avatarless embodiment. Instead, it comes down to a comparison of graphics quality. For example, Simulating Virtual Environments Within Virtual Environments [2] (which Kilteni et al. [3] claim as their reasoning for needing virtual avatars) asked participants to choose which simulation they felt most immersed in. Participants were presented with options ranging from a no shadows, no virtual body scenario to a completely rendered environment with a fully motion captured body. Users picked the most graphically advanced option. However, this doesn't prove that virtual avatars are crucial to embodiment as Kilteni & Groten claim it does, as there wasn't fair investigation into avatarless embodiment. There remains a gap in research around producing embodiment in virtual realities without a virtual avatar for the user to project upon.

2.2 Dance and XR

2.2.1 XR Dance Performances

Papers on performance pieces tend to have existing dance processes at the center of their design, in order to blend well with existing workflows. For instance, to combat how unfamiliar and unintuitive virtual spaces are to theatre practitioners, Farewell to Dawn [4] based their work on existing processes used in real physical theatre. They also state real time performance capture is essential, specifically because this is what is already familiar to the performers. Moura et al. [5] also show their commitment to existing dance practice by working closely with a contemporary dance company.

Primarily performances are focused on the audience experience over that of the dancer. Farewell to Dawn [4] purposely avoids the dancer to be fully immersed in the virtual world, but does discuss the possibilities for off-site audience immersion. Golz & Shaw's [6] iPad AR is only visible for the audience, not the performers. These decisions show their immersion priorities.

2.2.2 XR Dance Tools

Existing XR dance tools are used to promote experimentation and assist in education. The tools vary in their feedback methods. A Virtual Reality Dance Training System Using Motion Capture Technology [7], an educational tool, uses a visual avatar alongside numerical analysis to provide feedback to the dancer about their progress. Their detailed score breakdown allows students to identify their weaknesses, which the paper describes as vital for learning. Raheb [1] also uses visual feedback, but opts for a less literal avatar representation. Instead, Raheb utilizes particle systems and motion trails to provide a better understanding of the user's movement trajectories and motion through space.

2.3 Dance and Auditory Feedback

Akerly's 2015 study explores auditory stimuli and dance [8]. The dancers used the sound as a body location method to judge proximity to ground and the world around them. One dancer described how the audio made visual stimuli defunct, noting it didn't matter what their eyes saw, because their body would respond to what they were hearing instead of what they were seeing.

Their system encourages movement experimentation by creating variations in sound when new movements are produced by the dancer. The system doubles as an educational tool, as dancers know that if a sound does not repeat itself when they reattempt the same action they are not executing an exact repetition.

Akerly shows the potential for sound to be a compelling feedback tool for dancers, but it has yet to be tested in VR or alongside visual feedback. It is acknowledged that visual stimuli alone are not enough to fully immerse a user in VR [9]. By investigating sound alongside visual, we can investigate the potential for these feedback aspects to create an embodied experience for dancers in VR.

3 Methodology

3.1 Approach

An action research approach was used to iteratively develop key themes and findings informed by the feelings and sensations of the participants as well as the research team ourselves. Action research allowed for the pursuit of directions found to be compelling and the inclusion of intuition into the design process.

A series of workshops were held which exposed participants to various VR technologies. Insights from previous workshops guided the designs of the subsequent ones in alignment with the projects iterative approach. Participants were interviewed and encouraged to engage in group discussions to identify key observations and feelings about the technologies. Data was collected qualitatively. This was more suitable than a quantitative approach due to the subjectiveness of dance and the open-ended research intent.

The final experiment was a share-out exhibiting prototype scene demos. Each featured prototype was designed to target key findings from the iterative workshop process.

3.2 Workshop Designs

3.2.1 Workshops Overview

A series of four workshops were held to explore various VR technologies. Early workshops focused on existing technology, while later workshops explored technology created specifically for this project. Participants were a mixture of dance undergraduates, postgraduates, teaching staff and engineering undergraduates.

These workshops were iteratively designed, and their key findings determined the design of the final share-out's prototypes. These influential results are detailed in 4.1.

3.2.2 Workshop 1

Our aim for workshop 1 was to expose dancers to existing VR technology to identify which features and feedback they found compelling. Participants rotated between stations facilitated by the project team who encouraged ongoing conversation and recorded the discussions.

The VR technologies explored were Beat Saber (Demo), Google Tiltbrush, 360 video and Oh Shape. These technologies provided varying levels of body awareness requirements, open ended tools for creative practice and a range of VR feedback approaches. OhShape also includes a basic avatar representation in the form of a shadow projection.

After participants had tried the various stations, the group reconvened to do a somatic awareness exercise.

Participants were then split into groups and challenged to use a technology of their choice to create a short performance. These groups included a mixture of dancer and non-dancer participants.

Finally, the group reconvened for an open discussion about the workshop.

3.2.3 Workshop 2 and 3

Workshop 2 built off previous observations as well as introduced the exploration of perspectives. The technologies explored were a ceiling mounted 360-video feed streamed to a VR headset and a multiplayer version of TiltBrush.

The 360-video feed gave participants a “gods eye” perspective of the room. First, participants took turns wearing the VR headset to see the 360-video feed. Once the person wearing the headset had explored the view, they were asked to try to choreograph another dancer using the VR view.

Finally, two participants used the VR headsets explore the multiplayer version of TiltBrush.

Workshop 3 also explored the 360-video feed, however then participants included project consultants who were both remote and in the room.

3.2.4 Workshop 4

Workshop 4 introduced custom VR technologies built for the project based on findings from previous workshops.

First, participants explored the 360 3D point cloud feed. This used data from ceiling mounted sensors to recreate the room as a 3D VR representation for the user to traverse.

The rest of the workshop was spent exploring 3 scenes created in Unity which utilised motion data from an axis neuron motion capture suit. Dancers took turns wearing the suit while in VR themselves, but additionally explored the scenes while another participant was motion tracked instead.

The first Unity scene was the velocity-particle emission scene. In this scene, the movement data is represented by a series of particle emitters attached to points on the virtual body. The emission rate for each emitter is linked to the velocity of the point it is attached to, so the faster the point moves the more particles are produced. The VR user observes this as a second entity, rather than from the perspective of the particle avatar. While exploring the velocity-particle emission scene dancers requested the changing of several parameters, which were then adjusted and the scene relaunched.

The last two scenes used the movement data to have an impact on the virtual environment around the user. In one, movement of various body parts caused orbs in the sky to change colour. In the other, building-like cubes grew and shrunk depending on the movement of the dancer.

3.3 Final Share-Out

3.3.1 Overview

The final share-out took place over zoom. Participant were shown a series of seven scenes depicting a virtual environment reacting to a pre-recorded dance. The first 6 scenes were loosely grouped into pairs. One pair explored particles, another environment effects, and the third sound.

3.3.2 Particle Scenes

The particle scenes were a more developed version of velocity-particle emission scene in workshop 4. In the first video, parameters were changed off camera over time so that the particle representation of movement went from an abstract to a trace-like configuration. In the second video, the gravity parameter was increased significantly.

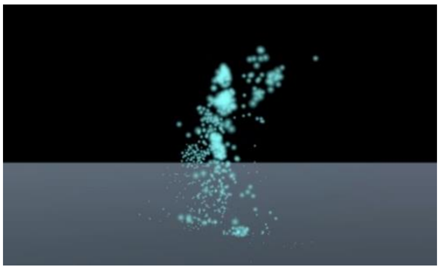


Figure 1 - Particle Avatar Example

3.3.3 Environment Scenes

The environment scenes were a scale-based scene and a procedurally generated terrain scene.

In the scale scene, the velocity of the dancer corresponds to the height of the virtual blocks. Different blocks respond to different parts of the body, for example, a group of blocks is affected only by the right arm.

In the second environment scene, average height and acceleration of the body impact the generation of the terrain. The height of the terrain is determined by the average height of the body. The granularity of the terrain was determined by the acceleration of the body. As the user moves through the terrain, it freezes in place behind them, leaving a trail that reflects their movement.

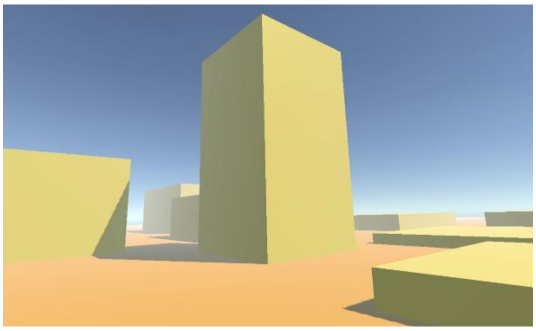


Figure 2 - Scale Change Scene

Figure 3 - Generated Terrain Scene

3.3.4 Sound Scenes

These scenes used sounds as representations of movement alongside visual feedback.

In the first sound scene, sudden changes in acceleration trigger different sounds to play and spheres to light up. There is one sphere for each hand and foot. These spheres are intermixed with other spheres that glow according to average velocity of the movement.

In the second sound scene, an ambient musical track is playing in the background. Spheres in the sky change colour corresponding with the velocity of different body parts. The floor oscillates at an amplitude that increases with fast movement and decreases with slow movement. A rushing air sound reflects the overall speed of the dancer.

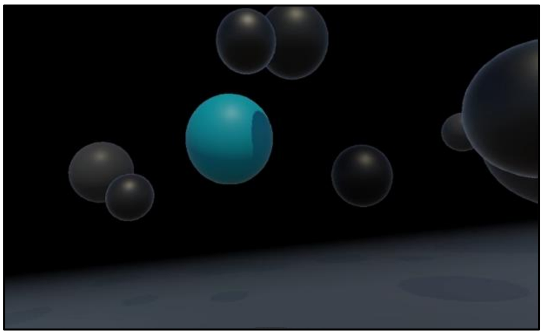


Figure 4 - Sound Scene 1

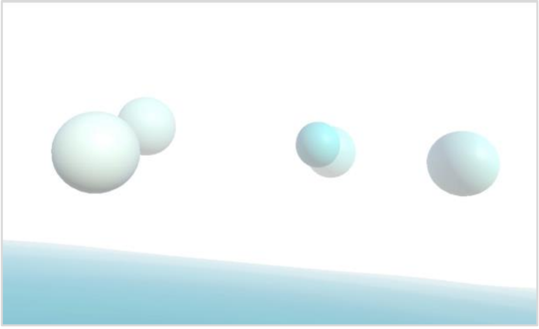


Figure 5 - Sound Scene 2

3.3.5 Particle Control Scene

The final video showed a VR user controlling the parameters behind the particle scenes via an in-game control panel. The parameters available for adjusting were as follows: minimum emission, velocity-emission multiplier, particle start speed, gravity, inherit velocity multiplier, particle lifetime, enabling collision, colour, and enabling or disabling different areas of the body. Participants could see the effects of these changes on the particle representation as they were made.

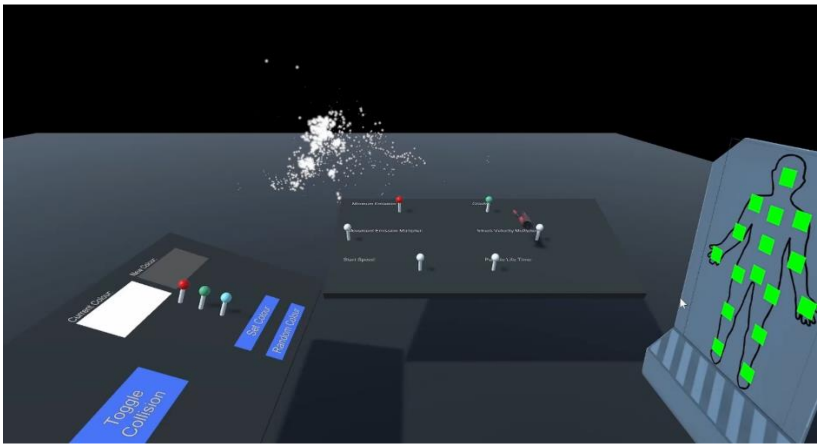


Figure 6 - Particle Control Panel

The maximum and minimum values of the parameters adjustable by sliders (excluding colour) are displayed in Table 1. These values were chosen through trialling to give a dramatic change between the minimum and maximum settings.

Parameter Name	**Min Value**	**Max Value**
Minimum Emission	0.0	20.0
Velocity-Emission Multiplier	1.0	10.0
Particle Start Speed	0.1	0.5
Gravity	0.0	4.0
Inherit Velocity Multiplier	0.0	6.0
Particle Lifetime	1.0	8.0

Table 1 - Parameter Minimum and Maximum Values

Most of these parameters directly access existing variables within Unity, however the velocity-emission multiplier and the minimum emission contribute to a custom linear function that determines Unity's emission rate over time variable. This function is detailed in equation (1), where x is the velocity-emission multiplier and y is the minimum emission value. v is a representation of velocity, calculated by taking the distance travelled of the emitter since the last update.

$$10000vx + y \tag{1}$$

3.3.6 Video Display Decisions

Each scene had been recorded from multiple perspectives. In some, an avatar representation was visible. This helped clarify what the environment was reacting to, however due to earlier findings around body judgement and the gap identified in avatarless research it was decided not to use those. The potential for showing the scene from the perspective of the dancer was briefly investigated, but it was decided that the harsh movement was unsuitable for audiences. Instead, it was decided to use a filmed VR perspective displayed alongside the real-life dancer to give context to the environment.

3.3.7 Data Collection

After each video was shown, participants were asked to record their initial thoughts in a google form. Once sufficient time had been given for this, researchers facilitated a group discussion. Feedback gathering was structured in this way to avoid participants responses from biasing one another.

Where possible, questions were prompted in an order that encouraged factual answers first and imaginative answers later. Factual impressions about the scenes were gathered before engaging in hypothetical scenarios, such as asking how a participant feels they would move within a scene.

4 Results

4.1 Influential Workshop Results

4.1.1 Non-Compelling Feedback

During this project a lot of technology was explored in attempt to discover aspects of VR feedback that are compelling for dancers. While some compelling aspects were identified and detailed below, equally important results were the aspects found to be non-compelling. These findings decided what we didn't bring forward into the final share-out.

In workshops 2 & 3 the 360 video-feed was explored. Dancers played around with the distortion effect caused by the perspective. When dancing with partners or choreographing they often requested the dancer stay low or change height frequently to utilize this effect. Dancers found this effect interesting, but ultimately stated that they didn't find any novel benefits to using the 360 video-feed over a regular video feed such as Zoom.

As part of workshop 4, a 3D 360 point cloud was investigated. Dancers enjoyed the "trace-like" and "shadow-like" visual glitches that pushed what they were seeing beyond a mundane recreation of real life. However, beyond that they didn't find the tool compelling for dance. This showed us that mirror recreations of reality are not compelling feedback for dancers in VR.

4.1.2 Body Judgement

In workshop 1, OhShape presented participants with a basic avatar representation of their bodies in VR in the form of a generic shadow. Participants felt this avatar representation wasn't them, and it caused a disconnect that made the visual feedback less impactful. We chose to move away from avatars and instead attempt to represent movement without necessarily seeing the human body.

4.1.3 Representation of Movement Through Time

Through experimenting with Tiltbrush in the first workshop, we identified dancers were compelled by seeing their movement through time represented. In tilt brush, this was represented as static traces. Tiltbrush was the technology participants chose to spend to the most time in, and when given the choice for what to use for the performance both groups chose to use Tiltbrush.

Participants found being able to leave an impact on the environment with their movement that they could then interact with compelling. One participant danced around their own traces while continuing to fill the space with more traces. Once the scene became too crowded, they made comments about how it would be interesting if the trace disappeared eventually. Dancers noted that only being able to track a hand felt limiting and hypothesized about tracking other body parts as well as tracking multiple at once.

The performances both utilised the concept of tracing movement through time. In one performance, a dancer followed pre-existing traces as a score for her movement. In the other, a participant in VR created traces through time while a second dancer out of VR traced this movement in using a piece of material.

These workshop results allowed us to identify representations of movement through time as a compelling VR feedback aspect. We pushed this concept in the particle and the procedurally generated terrain scenes. The particle scene explored both full-body traces and temporary traces. While the terrain scene explored a less literal representation of movement through time, showing its impact on the environment over time.

4.1.4 Desire for Sound

The workshops were largely focused on visual feedback, but participants frequently voiced the desire for sound. In the first workshop, one participant noted the lack of sound decreased his embodiment, as he was too aware of noises in real life. Akerly demonstrated the potential for sound as a compelling form of VR feedback for dance [8]. In the final share-out we investigated the potential for sound to enhance our visual feedback prototypes in the two sound scenes.

4.1.5 Parameter Impact on Movement

In the fourth workshop we observed the impact parameter changes have on dancer's movement choice. Changing variables around how scenes behaved or how responsive they were caused dancers to change their movement style in response. With the particle scene, participants appeared to be motivated by producing as many particles as possible. This meant that if the parameter configuration rewarded extra particles for sweeping motions, the dancers responded with sweeping motions. Meanwhile, if the parameter configuration required a high velocity to emit particles, dancers would respond with forceful stomps and jumps to produce particles.

This observation was carried through into the final share-out through the particle control scene. In this scene, users are given control over the parameters observed to impact movement choice.

4.2 Particle Scenes

While watching the first scene, participants were able to determine that there were some parameters that changed throughout the scene and began to put their own names to them. Most were able to identify gravity, one noting that they liked that the rule of gravity still applied in a virtual space. One participant described a parameter of energy, notably distinguishing between moments of “energy dispersion” and “centralised points of energy”. A participant who with a technical background discussed how important they think particle lifetime and velocity parameters are to changing the behaviour of the particles.

While watching the second particle scene, participants said they found it easier to distinguish the human form compared with the previous scene. They used words such as “grounded” and “heavier” to describe the impact the higher gravity parameter had on their experience. One participant likened the particle effect to trails of wind behind a moving body.

At this point participants began to discuss ideas for different versions of the scene, potential applications, and further explorations they were curious about.

A participant was curious about whether the program could be changed so the dancer could interact with previously emitted particles. This suggests that they want more impact on the environment around them. The participant may be voicing a desire to be creating more physical, tangible things rather than abstract representations of previous movement.

Another participant noted potential for the programme as a device to stimulate and challenge movers with a responsive practice. They described how they how participants with a keen sense of curiosity could try to discover the rules and triggers as part of a movement game. This suggests the correlation between the effects and the movement are still not fully clear to the audience, but that this concealment may still be compelling in a dance context.

Ultimately the scenes were similar, but the breadth of discussion between the two suggests that the novel differences in parameter changes were significant. This reinforces our findings that parameters are impactful and suggests that the parameters we identified to control are relevant.

During the final discussions, the particle scenes were identified to be among the most compelling scenes. Participants commented that the obvious links between the dancer and the effects were “ASMR-ish” and encouraged their body to follow, create and reimagine the movements. This resulted in a kinaesthetic response for them while watching.

4.3 Environment Scenes

For the two environment scenes, participants expressed they struggled with correlating the movement of the dancer with the impact on the environment. One participant noted how complex the moving human form is, and that while it was clear something was being captured, it was not the same information she was taking from the live dance video. This feedback highlighted the disconnect between the jagged movements of the scene and the sustained, smooth movement of the dancer. This mismatch made it difficult for participants to correlate the movement and get meaningful VR feedback.

One participant had a unique perspective to the other participants as she had experienced the scale scene in VR during workshop 4. She noted the difference between purposely making movement to impact the environment and watching a playback of disconnected improvised dancing. The movement she chose was more in line with the jagged movements of the scene. She jumped and stomped to try activating the floor, and found the scene responded in a way she expected. However, she noted that watching the improvised playback the scene was triggered in less expected and ultimately unclear ways. This once again highlighted how a disconnect between the movement style of the scene and the dancer obstructs meaningful VR feedback.

Participants saw more potential for development with the procedurally generated terrain scene than the scale change scene. They described it as disorienting but intriguing and expressed interest in trying it out in VR to push its boundaries. One participant described an expansion of the scene where the terrain is more realistic and more movement parameters could be linked to elements, such as rocks and trees. Another noted that it would be a cool technology to adjust for a performance piece. Contrastingly, very little imaginative ideas were volunteered for the scale change scene. This suggests that the participants found the generated terrain scene more compelling than the scale change scene.

4.4 Sound Scenes

Overall, there was a very positive response to the inclusion of music. Participants felt sound added another dimension to movement qualities and identified the sound scenes as among the most compelling in the final discussion. Movement triggering sound was described as satisfying and in both scenes participants found it clear to identify relationships between movement and sound. Participants successfully identified the sudden deceleration trigger of the first scene, as well as how the second scene’s sound reflects the overall speed of the dancer.

In these scenes sound was included alongside visual feedback. One participant noted that while there are sounds and animation at the same time, the first thing that comes through is sound. Another participant however found themself curious about extra visual details in the scene such as the size of the spheres, when in reality a relationship between that and movement was non-existent. This suggests that the visuals given alongside sound feedback in VR need to be carefully considered to avoid being distracting.

The second sound scene prompted discussion around rhythm. One participant stated they were able to visualise and pick out the dancer’s rhythm through the scene. The dancer of the improvised dance recording noted the rhythm felt boring, and when she realised her movements were producing that rhythm it made her want to change her dance. This suggests that sound reflecting rhythm is compelling VR feedback for dance.

4.5 Particle Control Scene

The primary response to this scene was excitement around potential applications. Participants noted an abundance of opportunity to use the tool to understand aspects of movement and choreography better. They theorised users could show the impact of one body part or initiation point to another or use the tool to understand how to polarize movement.

Participants thought it was interesting to give controls over to someone who isn’t necessarily the dancer. They discussed how this could potentially bring in an element of participation for audiences.

The one criticism provided was around the use of terminology. Participants felt the names for the parameters came from a technical perspective and would have preferred they aligned with a choreography background.

5 Discussion

5.1 Language and Terminology

A detrimental disconnect between the technical and dance was identified in language choices. Initially, participants were coming up with their own terms to describe parameters and effects they were observing. However, after the last video introduced technical terms, they became hesitant to describe their impressions of parameters. This limited the feedback we received and demonstrated how it would be difficult for a dancer to use the tool we had created.

By looking at descriptors participants used for scenes we can begin build a shared terminology. Figure 7 shows a word cloud of ways people described scenes in both the discussion and the survey. Many of these would be inappropriate as parameters, but others such as ‘energy’ or ‘rhythm’ show clear potential. These experiments were designed without intending to gather this data, but dedicated experiments would uncover more potential terminology.

Figure 7 - Participant Descriptor Word Cloud

Another approach to finding appropriate terminology could be directly translating chorographical terms into parameters, rather than trying to name the current parameters. This could be suboptimal as we have already identified compelling parameters.

Regardless of approach, in the future appropriate terminology will have to be investigated.

5.1.1 Natural Vs. Unnatural parameters

It is notable that participants were less likely to name parameters unobserved in reality. In both particle scenes participants named ‘natural’ parameters such as gravity or the collision of force on the ground.

However, parameters that don’t occur in real life were neglected. The closest a participant got to acknowledging the emission rates and velocity inheritance was to refer to the density difference as a change in energy, another observable real-life phenomenon. We chose to move away from recreating reality to utilise the potential VR provides, but when developing terminology this should be considered.

5.2 User Perspectives Framings

Perspective framings can be used to explore nuances between user requirements and potential applications for developed tools. Primary perspectives for this project are an audience perspective, a choreographer’s perspective, and the perspective of a dancer. When evaluating how compelling an aspect was, discussions would often originate from one of these framing, intentionally or not. By categorising the participants feedback into these framings, we not only understand what aspects of VR are compelling in a dance context, but what user group they are compelling for. This will increase the value of the results of this project.

5.2.1 Choreographer

A choreographer framing was most often expressed as ideas for potential applications of technologies. These ideas were volunteered in scenes where the correlation between movement and effect was clear. Participants discussed how they could use the sound feedbacks to generate a score. They also noted how understanding the rhythm of a scene, as the second sound scene facilitates, would be useful for a choreographer. Choreographic potential was also identified for the particle scenes.

Aspects identified as compelling to choreographers reflected a desire to understand the movement generated by the dancer in a clear way, but also a way that was more novel than just a camera feed. However, due to lockdown we were unable to ask participants to attempt choreographic tasks as we had in previous workshops. User testing would have to be undertaken to determine whether what participants identified as interesting from a choreographic perspective is also useful.

5.2.2 Audience

Aspects identified verbatim as compelling to audiences were visual in nature. The particle control scene and procedurally generated scene identified them as potential experiences for audience members. Participants noted that it would be interesting to have audience members use the control panel for the particles. This raises the question of whether the compelling aspect for the audience member is the visuals, or the control they are given over them. Further investigation is needed to determine this. Notably, both the particle control and the generated terrain scene were more technically complex. Therefore, an aspect participants could have been identifying as compelling is technical novelty. Audiences may be interested in performances with displays of technology they have not encountered before.

Overall, the results for what specific aspects are compelling to an audience perspective from the final share-out are not clear because participants were prompted to respond from their own perspectives. Participants foremostly utilised their backgrounds as dancers, and only as afterthoughts hypothesized about audiences. However, these results are still useful to build further workshops should the project shift towards focusing on an audience perspective. The insights they provide will build a strong foundation for further research.

5.2.3 Dancer

The dancer is the default framing most participants thought from. They were invited to workshops as dancers and brought this role with them into discussions. As such the majority of the reactions they were expressed were from viewing the scenes as dancers. It was a dancer framing that found traces of movement through time, parameter changes and use of sound to be compelling aspects of VR feedback, and it was a dancer perspective that voiced the desire to be in the VR environments and explore them with movement. As explained above, some of these also fell into other perspective framings, but by default the results of this project fall under the perspective of the dancer.

5.3 Design Decision Impact

5.3.1 Movement to provide feedback on

Decisions around what to represent from movement were made from a technically practical perspective. However, the final share-out result show more thought needs to be given to this decision. Discussions highlighted the complexity of the moving form. Multiple participants asked why we had chosen to represent certain movements. The mismatch in movement types between the dancer and the scale scene showed making decisions from a technically practical perspective is not sufficient to achieve compelling VR feedback.

Our intent had been to determine what was meaningful feedback to movement, however these results make it clear that the question of what to provide feedback on was equally important. In the future this will need to be investigated further.

5.3.2 **Clarity of Correlation**

Some scenes were designed to have clear links between the movement of dancer and the reaction in the scene. For instance, the particles form a partial avatar that allow the user to see glimpses of the human form. Contrastingly, other scenes were designed to be more abstract representations, such as the environment scenes.

Discussion was generated around how participants felt about clear links compared with less obvious correlations. Participants commented that the obvious links in the particle scenes were “ASMR-ish” and encouraged their body to follow, create and reimagine the movements. This resulted in a kinaesthetic experience for them while watching. Overall participants liked when scenes had obvious links as they felt it made it feel more related, rather than something separate that just happened to be occurring simultaneously. However, participants also noted that the less obvious links stimulated urges to figure out what the link is. They identified it as a potential movement game, and were eager to try those scenes in VR to explore them themselves.

Our results show that the obvious correlations are compelling, however they do not prove that the not obvious correlations are not. To determine this, investigation into their impact in VR will need to be undertaken.

5.3.3 Procedurally Generated Terrain Scene

The procedurally generated terrain scene was developed without access to a VR headset due to lockdown constraints. Design decisions were made without being able to test in a VR perspective. This resulted in the scale of the scene being inappropriate, and lead to the concept of leaving a trace of movement through time not being adequately displayed on the video. Resultingly, representing movement through time in an abstract way was not sufficiently investigated.

5.4 Future Work

5.4.1 Combination of Feedback

The final share-out results found that the particle representation and sound are compelling forms of VR feedback for movement. Sound successfully enhanced the visual feedback in the prototype sound scenes, but it remains to be tested whether it would be equally compelling in combination with the particle representation. In the future different combinations of feedback could be tested to evaluate their impact alongside each other.

5.4.2 More Extensive VR Testing

Due to lockdown, we were unable to test the prototypes with dancers in them. Additionally, many scenes were developed without access to a headset. Resultingly there will be aspects to improve from a user experience perspective as well as insights to gain from dancers experiencing the scenes for themselves. In the future, more extensive VR testing will need to be undertaken.

5.4.3 Multiplayer/Remote Collaboration

A theme consistent through the workshop was collaboration between dancers. In the first workshop the performances demonstrated a desire for both synchronous and asynchronous collaboration. In the subsequent workshops participants explored the technologies together, with one participant in VR and another interacting in a way that impacted their experience. Due to the relevance of Covid 19, discussions were brought up about the potential for utilising VR for remote collaboration. We briefly investigated multiplayer TiltBrush, but soon discovered modifying the program further was infeasible. With no existing multiplayer tool to build off, it was determined that multiplayer was out of scope for this stage of the project. This is definitely an important area to explore in the future.

6 Conclusion

This project explored dancers' experiences of various VR feedback with the aim of iteratively developing a compelling VR experience that elicits embodied dance movement. Through a series of workshops, we came away with key findings that determined the design of the final share-out prototypes. Our final share-out results show that we were successfully able to create compelling VR experiences.

Participants found the sound and the particle scenes to be the most compelling, however they struggled with correlation between the scene and the dancer for the environment scenes. This identified a need to unify the disconnect in movement style between the dancer's actions and the scenes reactions, as well as a requirement to consult with dancers on what elements of movement to give feedback on.

Another detrimental disconnect identified was in language choice. Technical terminology for parameters isolated participants and will make it difficult for dancers to use the tool created. This report discussed terminology generated in the share-out and identifies possible paths for uniting the technical and dance vocabulary in the future.

Many avenues have been explored and many more have been identified for future work. Our project has successfully identified compelling aspects of VR feedback for a dance context. This information will support further iteration towards a VR tool that is effective for dance.

References

[1] K. El Raheb, G. Tsampounaris, A. Katifori, and Y. Ioannidis, Choreomorphy: a whole-body interaction experience for dance improvisation and visual experimentation. 2018, pp. 1–9.

[2] M. Slater, B. Spanlang, and D. Corominas, “Simulating Virtual Environments within Virtual Environments as the Basis for a Psychophysics of Presence,” vol. 29, 2010, doi: 10.1145/1833351.1778829.

[3] K. Kilteni, R. Groten, and M. Slater, “The Sense of Embodiment in Virtual Reality,” vol. 21, no. 4, pp. 373–387, 2012, doi: 10.1162/PRES_a_00124.

[4] F. Caputo et al., Farewell to dawn: a mixed reality dance performance in a virtual space. 2016, pp. 1–2.

[5] J. M. Moura, N. é Barros, and P. Ferreira-Lopes, From real to virtual embodied performance - a case study between dance and technology. 2019.

[6] P. Golz and A. Shaw, Augmenting live performance dance through mobile technology. 2014.

[7] J. Chan, H. Leung, J. Tang, and T. Komura, “A Virtual Reality Dance Training System Using Motion Capture Technology,” vol. 4, pp. 187–195, 2011, doi: 10.1109/TLT.2010.27.

[8] J. Akerly, Embodied flow in experiential media systems. 2015, pp. 9–16.

[9] J. Bailey, J. Bailenson, and D. Casasanto, “When Does Virtual Embodiment Change Our Minds?,” vol. 25, 2016, doi: 10.1162/PRES_a_00263.