

Practice Discovery: *Replica* by Displace Studio

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Abstract

Replica is an immersive Mixed Reality (MR) dance performance by Displace Studio, made in partnership with the Virtual and Immersive Production Studio (VIP Studio) at the University of Nottingham (UoN). This article discusses the technical and creative development of *Replica*, a one-to-one audience experience, exposing the technical and production pipeline, and highlighting the experimentation used to capture the dancer volumetrically, often subverting the normative use of Volumetric Capture. *Replica* was made through an iterative design-led process of prototyping and user testing, evidencing that audiences have much to contribute to MR immersive works, especially in relation to embodied experience, intimacy and connection. The discussion traces the conceptual, choreographic and technical development, outlines the team's approach, and documents the oscillation between technical potentials and creative decisions. Also discussed are platforms of engagement for larger audiences, including a multi-user MR version and an external Augmented Reality (AR) camera system screened to a seated audience, with the potential for a livestream for remote viewing. This hybrid engagement addresses a sector challenge of scaling Extended Reality (XR) works for sustainable touring yet reveals tensions between the artistic presentation and its viability for venues. Also highlighted is the value of partnerships between independent artists and production facilities, in terms of access to resources, peer-to-peer learning and sharing expertise, towards developing a more equitable immersive production ecosystem. Throughout our discussion, we argue that immersion and intimacy are created in *Replica* through a mix of diverse sensory sources (space, sight, sound, touch), perceptual integration of those sources, and the mediating qualities of passthrough itself; to visually combine the real and virtual as through a lens.

Keywords: dance, volumetric capture, mixed reality, intimacy, audience, virtual production

Watch a trailer of *Replica* [here](#)

Introduction

Replica by Displace Studio is an immersive Mixed Reality (MR) dance performance made as a Digital Commission for The Space in partnership with Near Now, Broadway Cinema, the Virtual and Immersive Production Studio (VIP Studio) at the University of Nottingham (UoN), De Montfort University (DMU), and Fabric Dance.

Replica makes innovative use of Virtual Production (VP) technologies centred around the integration of a live dancer with a pre-recorded Volumetric Capture (VolCap) of herself. It utilises the passthrough capabilities of the Meta Quest 3 Virtual Reality (VR) headset to display the virtual dancer - who occupies the same space as the live dancer - allowing her to duet with her digital double. Passthrough is the ability to view the real world while wearing a VR headset (through its cameras, seen as if through your own eyes), with the addition of virtual imagery overlaid.

This article exposes the production pipeline, highlighting the experimentation used to create the piece, and how audience experience was central to its design. By drawing on feedback gathered from audiences to evidence the impact of this MR work, the project contributes to wider research on scaling XR works, carefully balancing increasing audience numbers whilst maintaining artistic integrity. This is discussed alongside the creative and choreographic development of the work, foregrounding the work's key concepts of intimacy, representation and authenticity, themes often explored in Displace Studio's work - work that aims to create 'deep, interpersonal, immersive experiences that encourage audiences to step into, behind, and around the edges of illusion' (Displace Studio).

Replica evolved through an iterative, design-led process of prototyping and audience testing, which resulted in the development of multiple modalities for hybrid engagement:

- A one-to-one experience - consisting of a live performance by dancer Kim Bormann with a single audience member wearing a headset
- A multi-user version - in which the one-to-one experience is observed by additional participants wearing headsets in the performance space
- A screened AR view of the MR experience using an external camera system - for a seated audience in the performance space
- A livestream of the AR camera view - for remote viewing

This article reflects on the relationship between VP and creative practice in the development of *Replica*, revealing the oscillations between technological potential, creative/aesthetic decisions, and a live performance; and how these intersect with digital dramaturgy and wider audience experience. Ultimately, this article explores how intimate MR performance work is created, experienced, and how it can be translated and scaled to reach wider audiences without losing its artistic integrity. It also outlines how *Replica* uses a hybrid sensory format with multiple forms of media all operating together - with the live body, volumetric captures, physical furniture, sound, choreography and visual effects combining simultaneously to create a deep and rich immersive illusion. These

contributions are useful to creatives and researchers working within performance and technology and the wider immersive arts sector, as well as contributing to current debates around sustainable touring and distribution models.

Context

Displace Studio was co-founded by Digital Dance Artist Kerryn Wise and Creative Technologist Ben Neal. Their artworks often involve encounters with real performers presented as volumetric captures embedded within a virtual environment or live performance. Their work *Replica* combines live dance, MR and VolCap, and during the 10-minute performance, audiences discover how it feels when real and virtual performers interact in real time (Figure 1). The piece explores the relationships that evolve between the live and virtual performers and the audience member, to further understand mixed realities, authenticity and notions of intimacy. Maria Chatzichristodoulou and Rachel Zerihan suggest that intimate performance works made across contemporary performance, live art and digital technologies can act as ‘catalysts for improved understanding, awareness and empathy with ourselves and for our other; human contact of life made art (made life)’ (2012, p. 11). Central to *Replica* is the unique relationship created between the audience participant and the dancer. Intimacy in this context is understood as a shared experience enhancing closeness through technological means (Chatzichristodoulou and Zerihan, 2012, p. 3), in which audiences’ ‘presence and sentient involvement’ (Machon, 2013, p. 26) is central.



Figure 1: View of the live and virtual dancer in *Replica*.

Image Credit: Julian Hughes/Displace Studio

Thematically, *Replica* invites audiences to consider human issues around liveness, mortality, memory and ageing – exploring how we connect in a world of growing digitalisation. It also provokes thought around digital doubles, ownership of movement, synthetic performers and cloning. The work examines digital archival processes and considers the ethics of how we present ourselves in an ever-increasingly digital society where there is pressure, especially on women, to curate an image, maintain a digital presence, remain youthful, and build a status by presenting ourselves through online profiles and alter egos - even if what we show is unrealistic, incomplete or misleading (Tiggemann, & Anderberg, 2020). It also critically intersects with highly-charged current debates about the ethics of using AI to synthesise performance (Thomas, 2024), highlighting how these extend beyond voice and likeness to encapsulate movement also.

Dancer Kim Bormann has been captured at a specific point in time, yet as the project develops over the next few years, each time she performs live, her body and face will be slowly changing as she ages. Despite this, she will not be asked to alter her appearance (such as cutting her hair) to try and remain identical to her replica, and Displace are interested in seeing how this might highlight notions of authenticity and transience in the work. They are also interested in the degradation of VolCap technologies as the technological landscape shifts and changes.

Through developing Displace Studio's previous works, it was found that VolCap has filmic qualities that enhance emotional intensity for audiences and point back to its moment of capture, which may evoke nostalgia or connection in audiences in the same way you might view an old photograph (Wise, 2025). In this way, it may continue to convey emotion and authenticity. The 'affective affordances' of VolCap are noted by Harry Wilson, who, when discussing artists' documentary performance, states that 'volumetric images have been utilised ... as a way to make their audience-participants feel more viscerally with the stories and encounters that they represent' (2026).

Replica was developed through a series of residencies at UoN's VIP Studio across 2023-2025, and this ongoing relationship with the studio allowed the work to develop iteratively, as successive stages of funding were secured and the work evolved from a single-audience-member experience into the multiple modalities for hybrid engagement discussed here. Established in 2023 as a space for practice-based research, a core aim of the VIP Studio is to make expensive immersive production accessible to creative partners in the region. It is recognised that the production of MR experiences relies on ecosystems of creative collaborators (Kennedy and Atkinson, 2018). Working in this way serves to make immersive production more sustainable through the sharing of resources; both in terms of equipment/space and skills/expertise. Performance-led projects push the boundaries of technologies and processes (Benford et. al., 2013), leading to innovations like the new software systems developed for *Replica*.

During the initial residency, the team explored capturing using Depthkit Studio with playback on a PC, seen via the Varjo VR headset. These early tests established the capture process (including hard lighting during capture instead of dynamically in software), the use of passthrough, the use of chairs as physical props and digital duet tests. This allowed the team to develop a proof-of-concept and documentation, which helped Displace secure further funding. They were then in a position to bring in wider collaborators, including performer/co-choreographer Kim Bormann and sound designer Dan Frazer, before moving into the main production period.

The one-to-one version of *Replica* premiered at Lakeside Arts (Nottingham, UK) in 2025, after two user testing sessions at BOM (Birmingham, UK), and Dance East (Ipswich, UK). *Replica* was presented at Art*VR Festival (Prague, Czechia) in late 2025 as a one-to-one and multi-user audience experience, and was a Finalist for the Lumen Prize 2025 (Music and Performance Category). In 2026, further research and development (R&D) was supported by CreaTech Frontiers.¹

Choreographic and Conceptual Development



Figure 2: Early tests layering a real and virtual performer using a single depth camera capture. As if seen through the VR headset.

Image Credit: Displace Studio

Displace did some early testing at Near Now, Broadway, Nottingham with a single depth camera capture of Kim (Figure 2), where they experimented with overlaying and merging the live and

¹ *CreaTech Frontiers is funded by the Arts and Humanities Research Council (AHRC), part of UK Research and Innovation, establishing a West Midlands CreaTech ecosystem by funding collaborative R&D, supporting business innovation and developing skills and talent.

virtual bodies. This began the process of understanding what might be possible choreographically and spatially by combining the real and virtual dancers. Kerryn made notes in her journal that 'size/scale is crucial' and when watching the duet, that 'It feels like they are a refraction of light, beings, versions of self'.

There is always a need to consider the practical processes alongside the creative development. It is important to understand what is possible technically, imagine the audience experience, and develop the choreographic work that brings together all those elements: technical, audience, and artistic intention. The team were careful not to allow the technical constraints to limit the artistic vision, yet it is often an ongoing dialogue between the technological possibilities and aesthetic choices. At this stage, the logistics of timings and synchronisation of how Kim might perform the work live were not considered in detail, and development focused on how the dance might communicate the themes and the relationship between the two dancers; one live, one virtual.

Once work started in the studio, the theatrical staging, comprising a table and two stools, had been considered, so the spatial configuration and where the audience would be seated was known. This led to the choreography being centred around the table, which would be placed centrally in the space.

Kerryn began to generate a series of themes and choreographic tasks to develop the movement ideas with Kim. They worked organically, improvising in response to the concepts and spatial parameters to generate the movement sequences. Kerryn choreographed this as a duet, imagining the replica's positioning and movements in relation to Kim's live action. Later, this enabled them to identify which parts of the choreography would need to be captured. In essence, Kim was learning two parts of the choreography, which would then come together in the final artwork.

After a series of choreographic development days, they created seven short scenes in response to the early experimentation:

1. Escaping our own body/image/past
2. Re-finding our identity
3. Striving for perfection and losing control
4. Regaining control
5. Exhaustion
6. Reflection and Recovery
7. Finding human connection and letting go

Kerryn sketched these out to map the performer and audience journeys and to communicate this to collaborators.

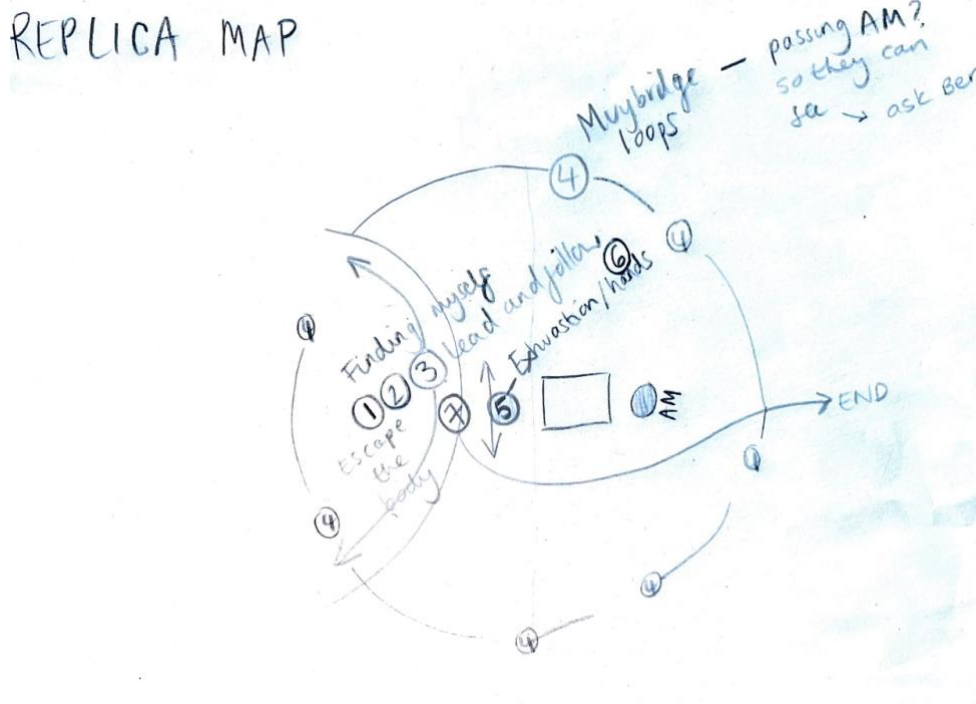


Figure 3: Sketch Map of Replica Scenes.

Image Credit: Displace Studio

This map (Figure 3) allowed the team to start to consider the overall trajectories of the work (Benford et al., 2009), and by planning out each scene, they were able to start to understand what would be captured for the virtual dancer's choreographic content.

Choreographically, *Replica* explores doubling, mirroring and overlapping bodies as the live and virtual performers merge, sync, glitch, oppose, chase, compete and synthesise with one another. The live performer gradually becomes exhausted as she attempts to keep up with the virtual, yet in contrast, the virtual performer is stuck in a rigid, ever-repeating loop.

Alongside the choreographic development, Ben was developing the technical elements. The Quest 3 headset was chosen as a less expensive, untethered and tour-ready alternative to the Varjo (which is expensive and tethered to a PC to run). It also has a smaller form-factor, allowing users to be closer, freer and feel less burdened, leading to improved interpersonal connection. Some development work was done for PC-based delivery; however, to take advantage of the Quest's native hand-tracking (explored but eventually abandoned), room scanning, spatial anchor systems and the potential for multiple devices, the decision was made to develop using Meta's Software Development Kits (SDKs) as a Quest standalone application. However, a large amount of testing and optimisation was required to ensure that *Replica* could be delivered on a much less powerful device, illustrating the capacity that needs to be built into projects seeking to identify the most appropriate hardware and software combinations for the particularities of a MR performance.

Capturing Process

The team recorded the VolCap at the VIP Studio over just two days with support from Dr Richard Ramchurn and Dr Paul Tennent, with additional exporting and processing done with PhD student Emily Trappen. The VIP Studio is one of the very few facilities with a full Depthkit Studio license in the UK, and the expense of the subscription and the equipment required to run it was well beyond what Displace Studio could have afforded alone. Kerry and Ben have a preference for VolCap - in which a performer is digitally recorded and presented as themselves - over other options such as Motion Capture, where the performer is presented as an avatar, and the original performer is more disguised or characterised.

VolCap is a VP technique that allows the surface of a three-dimensional form to be recorded and played back over time as both colour and spatial data. This is usually reconstructed in a 3D virtual environment, although it may be rendered as 2D - for example, as a video. There are a range of software and hardware options available for VolCap. For this project, Depthkit was used (by Scatter - now owned by Evercoast) and the Microsoft Azure Kinect cameras.

The Kinect cameras provide depth data (1 megapixel depth) alongside colour data (12 megapixel RGB), which can be streamed and recorded. This allows the reconstruction of the subject, not only visually, but also as a spatial form. In this manner, a performer can be captured and then rendered as a moving 3D object, which can be viewed from any angle. However, depth cameras can only record from a single perspective; therefore, parts that are obstructed and out of shot (eg, sides facing away from the camera) are omitted. To fill in these missing perspectives, additional cameras can be added to the rig to provide the data from the back, sides, above and so on. The cameras need to be carefully placed and configured to create a comprehensive, overlapping network with shared spatial reference points. These additional perspectives are often then merged to create a single composite form.

The Depthkit software can be used to easily record, render and playback VolCap data. It also allows various camera profiles (e.g., exposure, frame rate, etc.) to be used, basic editing/clean-up (e.g., trimming, floor and background removal) and file exports. The main file format is known as a CombinedPerPixel video, and this combines both colour and depth data into a compressed mp4 video file suitable for high-performance data streaming. These video clips can be imported into the game engine Unity (along with other metadata) and played back using a Depthkit Player plugin. Depthkit does not record sound, and the sound was not captured on set: music was later composed specifically for the clips, once the sequence was defined.

VolCap is usually used with low-motion subjects, with a small footprint, and viewed from one set angle. In *Replica*, a combination of techniques was used to move the VolCap around a relatively large 6m x 6m space, often at speed, and it was to be seen from many angles. Using VolCap for dance comes with a series of issues, as dance requires room to move, and as such, the size of the

capture volume is key to what is possible. A larger space requires more lighting and, crucially, more cameras, which then need to be configured and combined, meaning ever higher processing demands on the computing equipment. Furthermore, increased distance from the camera degrades fidelity. Entrances and exits can be problematic for VolCap since clips are cut in/out when recording starts and stops. Fading and dissolving are possible using visual effects, but blending clips together is another problem area. Thus, shot transitions were necessary due to the changes in camera configuration and the large area covered in *Replica*. For each shot, an approximate start and end position was established and a pose to use, which would lead from the previous and into the next clip (as is common in animation using blend trees). Later in development, these cut-points were further covered with visual effects and colour changes to somewhat obscure them. Occlusion is a common issue in VolCap when areas of the body are hidden from the camera's view. This is more problematic with a lot of movement and when limbs cross the body. Multiple cameras help this situation, but it's very difficult to have complete coverage.

The performance was cut into scenes/segments with different camera set-ups - a close-up, a wide, and an inside-out configuration. VolCap can sometimes be a fewer-is-better situation where cameras are concerned, so that overlapping perspectives are minimised to avoid seam lines and join points. Each configuration had a different number of cameras at different positions and with necessary changes in lighting to allow the cameras to be placed closer in scenes with less movement in order to capture more detail (in particular with regard to the face and hands). Rather than limiting performance options, the team experimented with a range of configurations.

VolCap can be rendered as a point cloud or a mesh (and more recently as Gaussian Splats). While point clouds retain something of the granular nature of flowing materials, meshes tend to display surface texture and detail better. *Replica* renders the VolCap as a mesh, which conveys a better sense of presence and facial detail (allowing better recognition and therefore relation to the real Kim) while sacrificing the realism of non-solid and flowing materials like hair and loose clothing. In addition, the optical characteristics of the Kinect cameras affect the volumetric forms - it is important to note that frame rate, image resolution, shutter speed and factors like motion blur contribute to the underlying geometry.

Having worked with VolCap on two previous dance works, *Facades* (2021) and *Tableau Vivant* (2023), Displace Studio had already worked with some of these issues (Wise 2024); however, *Replica* came with its own set of challenges. The team had quite limited lighting options available and could not use the greenscreen volume since the performance space was so large. This meant that captures had to be done in a bigger, but less controlled working space (Figure 4).



Figure 4: Preparing to shoot the table scene.

Image Credit: Displace Studio

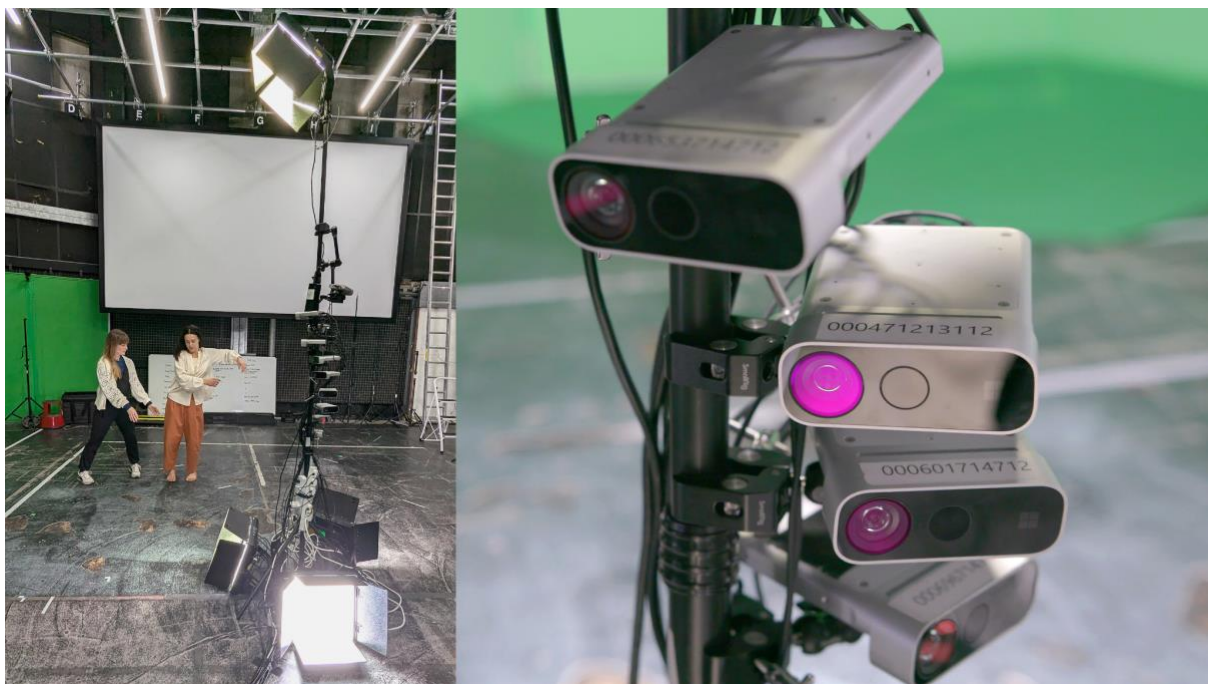


Figure 5: Image of the inside-out VolCap rig.

Image Credit: Displace Studio/Georgianna Scurfield

Kerryn and Ben wanted to work within the constraints of the technical processes, without hindering the artistic vision, and this meant that the team had to work creatively to find solutions, often using the technology in unusual ways.

The digital loops scene, in which Kim spirals around the audience member who sits centrally, was shot using an unusual inside-out camera configuration (Figure 5), in which the cameras were clustered into an array around a central column and faced outwards. This is a scene in which the VolCap becomes a ring of 10 single-perspective views. The decision to move to a single-perspective here allowed the choreography to be more dynamic and expansive, and cover a larger space around the viewer. In this scene, there was less need for a full 360-degree virtual performer, since the audience member would be seeing this from a centre point. In addition, during the looping, the virtual performer becomes duplicated and at times frozen in space, creating a ring of freeze frames around the audience member, to which the real dancer later returns (Figure 6). The freeze frames were created by exporting chosen frames as 3D model files and then adding them to the scene at the exact frame they were taken from, giving the effect of the VolCap leaving frames behind as sculptural objects. In addition, a doubling effect was achieved by carefully editing together multiple Depthkit videos into a single composite clip, which allows the virtual performer to appear briefly in multiple locations simultaneously using just a single clip.



Figure 6: Image of the freeze frames.

Image Credit: Displace Studio

Software Development

To control and fully integrate the virtual content, Ben built a Unity framework to position, render and play back the VolCap sequences. Its primary function was to play Depthkit clips sequentially with controls such as play, stop, pause, skip, loop section, as well as speed control - all of which were used in development to review transitions, and in rehearsals to practice particular parts. Each clip's start and end points could be adjusted to try to find optimal clip transition points, and it

allowed multiple takes of a single shot to be sequenced while final decisions were made about the choreography. Even when reliant on the affordances of proprietary software, additional technical development is needed to ensure creative requirements can be met.

Depthkit has various players, and due to the performance limitations of rendering a 10-camera VolCap on a Quest 3 VR headset, the Depthkit Lite player was used. The Depthkit Lite player is designed for better performance on low-specification hardware and does not merge camera views (instead it simply aligns them alongside each other). Despite its limitations and lower quality, the sense of presence is retained.

To create a richer MR experience, Ben used Spatial Anchoring to place a virtual table at the same position as the real table. This is used to anchor the virtual world and is a fixed reference point in space between the real world and the virtual world. The virtual table not only anchors both worlds to the same spot, but also uses an occluding shader to create visual holes in the VolCap - so it is not visibly overlaid above the real table. This leads to the illusion of the replica sitting at the real table - as the virtual dancer's legs cannot be seen through/above the real table top. This shared spatial positioning increases the sense of presence as both real and virtual elements share the same physical space, leading to an increased sense of co-habitation and coherence, allowing the audience to perceive one continuous world.

Alongside this, passthrough was enabled to allow the real world to be seen with virtual content overlaid. Transitioning with volumetric captures cannot be done through morphing (as can be done using motion blending - e.g. with motion capture data), so transitions are more akin to video cuts where blends or mixes can cover cuts from shot to shot. In *Replica*, it was found that fading to black at the end of a clip and fading back to colour at the start of the next clip helped smooth the visual cutting. A chromatic aberration effect was also used to glitch clips during a transition, so jumps in position are less noticeable.

Once the shot sequence was finalised, many of the frames from the CombinedPerPixel video clips were carefully cleaned up by Ben in image editing software (a labour-intensive task to remove unwanted debris, floating particles, floor and background objects - some of which could have been avoided with cleaner captures). Often painstaking by-hand work is needed to achieve the digital product, and this needs to be factored into budgets for immersive projects.

Performance Methodologies

Using an early demo, Ben, Kerryn and Kim gathered in the Fabric dance studios to test bringing the live and virtual performers together. In *Replica*, it is vital that sound, movement, physical objects and virtual bodies function as one system. This process posed a range of challenges regarding how Kim would be able to duet with her virtual double, which she could not see. The team decided to rely on some traditional dance techniques involving real spatial markers on the floor, coupled with sound cues. The audio was developed in response to the captured scenes and

segmented (since clips are loaded individually and not along a timeline). After the main music was composed, Ben and Kerryn asked sound designer Dan Frazer to add very specific, yet subtle, sound cues that Kim could use to stay in time with the replica, and to know when key choreographic changes occurred. The music is played through a speaker system in the performance space and allows Kim to hear the musical cues - this also acts as an additional real-world anchor for the audience.

A useful feature of the MR software is that while wearing the headset, Kim can load scenes and follow her digital double to rehearse; Kim described this process helping her to re-embody the movement and memory of the replicas' performance, which is different to her live choreography. It also doubles as a positional tool when preparing the performance space by showing the exact positions to put small tape markers on the floor, which allow Kim to get her positioning correct in the live choreography.

While the software is in use, it is possible to cast the view from the headset to a laptop, which allows others to see what the wearer sees. This means a technician can monitor the performance through the audience member's eyes, for one-to-one performances, to ensure everything is as it should be. Casting was also vital to the choreographic process to allow Kerryn and Ben to both see and analyse the experience from the perspective of the audience.

Kerryn found it interesting to work with Kim to develop this performance and rehearsal process. Kim had limited prior experience working with VR, and they collaborated on finding methods that worked. During the first few sessions, Kim would wear the headset and perform the replica's movement sequences to understand them spatially and somatically. She then moved into performing her live part with a felt, kinesthetic memory of what the replica was performing at any given time. This process began quite practically, finding the precision in the movement and the dynamic and spatial qualities. Then they worked on fine-tuning Kim's live performance skills to communicate the relationship between the two performers at different moments. Kerry Francksen highlights new performer capabilities through working in digital environments, stating that 'managing the technological precision, whilst simultaneously exploring the imaginative possibilities (the storytelling) of any digital theatre environment, requires a new sensibility of the creative process' (p.38, 2024). Kim developed a unique set of skills through the production of *Replica*. She was able to hold the physical imprint of the replica and then duet with that physical memory, whilst also performing the live choreography, communicating the themes, and responding to the audience member and their behaviour inside the performance space.

Kim was also negotiating her live presence in each performance. To sustain a dynamic energy in the performance - to counter the replicas' pre-determined condition - moments were added when Kim could improvise with parts of the choreography. This allowed Kim to respond to each audience member individually and work with her energy levels. She reflected that when

performing the work (sometimes up to fifteen times a day), this helped her to stay engaged with the present moment, connect with the audience member, and keep her performance alive.

User Testing and Feedback



Figure 7: Audience member experiencing Replica.

Image Credit: Julian Hughes

User testing was an important part of the iterative design-led process of *Replica*. A multi-method approach combined interviews with audience members at venues after the performance (21 conducted), and an online questionnaire that could be completed on site or subsequently (47 responses collected), thereby maximising opportunities for participation. Questions probed how comfortable audience members were during the experience in terms of their awareness of their own body, the live performer and the physical environment, as well as their emotions and whether they felt part of the performance. They were also asked about their understanding of the relationship between Kim and the replica and which they felt most connected with. Data was used with The Space's evaluation framework to define a set of intended outcomes for audiences, creators and the wider world (Chianta, 2026).

Themes of intimacy, proximity and connection were explored with audiences, who start and end the experience very close to both the real and virtual performers. On entering the performance space, the audience member sees Kim and the replica prone on the small table and is seated directly across from them. Not only is this unusually close, both in terms of proximity to a live performer

and viewing position for digital content, but the intensity is also heightened by the presence of three bodies in the space for two. Audience feedback affirmed that this positionality is a powerful starting point for the relationship between the audience and performer(s). One interviewee explained, 'I came into that space and felt very close to her', while another said they 'immediately felt a sort of compassion for the person in front of me'. An important observation is that the headset serves to mediate the experience, creating what several users described as a comfortable 'distance' between the audience member and the performer(s). Therefore, MR creators have an opportunity to design forms of relationship and interaction between performers and audiences made possible because passthrough acts as a layer through which the real and virtual are jointly experienced, with the headset screens enabling perception, but also serving as a mask and lens. Furthermore, intimacy emerged not from realism, but from a combined perception of physical, virtual and mediated presence.

At the end of *Replica*, both Kim and the replica return to their starting position at the table. Kim is physically tired, breathing heavily and sweating by this point, which heightens the sense of intimacy for the audience member, 'knowing that there's a real human there', as one interviewee put it. The replica remains prone; one survey respondent told us, 'I did feel the urge to comfort the virtual dancer when she returned to slumping over the desk', indicating the authenticity of the relationship established. However, despite her 3D form, the replica can never make physical contact. In contrast, physical touch becomes a powerful moment of connection for audiences after the replica disappears, when Kim sits up, makes eye contact with the audience member and reaches out with open palms to them across the table. Some audience members respond to the gesture by taking her hands (Figure 7), while others choose not to.

Users describe uncertainty about what is allowable/acceptable within the physical performance encounter, questioning their instincts to make a physical connection: 'I didn't know whether I should have touched the performer, it was like an invitation, and I didn't know whether I should do'. One interviewee draws parallels with the work of Marina Abramović, and it is interesting to think what we can learn from this. At one end of the spectrum is the potential threat posed by the audience if given agency and control over a performance (*Rhythm 0*, 1974). Punchdrunk is known for giving their audiences masks and rules to ensure respectful relationships with performers (Biggin, 2017), and it is interesting that the affordances of the headset seem to serve this function in *Replica*. At the other end of the spectrum is the desire for connection (and witnessing connection) with a performer without physical contact or dialogue (*The Artist is Present*, 2010), which was the approach of some *Replica* audience members in their final moment sitting across the table from Kim.

Ultimately, regardless of their personal response to Kim's proffered hands, audience members identify the end of *Replica* as a 'unique', 'rare', 'powerful', 'personal' moment, which elicits strong emotional reactions, including becoming tearful, smiling and/or thanking Kim and, on some occasions, asking to embrace Kim. The move away from digital doubling, back to reality and

human physicality, may be why some audience members find *Replica* so moving in its closing moments. This tells us something very important about MR experience design related to a point made by a pioneer of this technology, Jaron Lanier, who argues that the removal of digital augmentation is ‘the most special moment’ because ‘you see the world with fresh eyes’ (Funk, 2025). Despite wearing a headset, the final intimate moments of one-to-one contact in *Replica* were profound for audience members: ‘that’s got such an electrical charge to it that makes it incredibly different’.

However, reflecting on the experience, one interviewee commented: ‘Intimacy can be really precious, you can create a special form, but at the same time, I guess it can also be intimidating or even oppressive, you know, uncomfortable’. This range of interaction preference is a consideration in our design-led process, alongside the inherent access limitations of a performance involving a single dancer and single audience member.

Scaling

As part of ongoing R&D, several ideas are being explored to see how *Replica* might work with multiple audience members. Displace Studio are keen to find opportunities for scaling that maintain the artistic integrity and intimacy of the work, whilst offering the scope to reach larger audiences and make the work more financially sustainable - a key challenge for the sector. The value of immersive, participatory experiences is inherently personal (Pine and Gilmore, 1998) yet companies such as Punchdrunk (Biggin, 2017) and Secret Cinema (Atkinson and Kennedy, 2022) reach large audiences with the experiences they design. While very large audiences are not the vision for *Replica*, the team are interested in making the performance more accessible, including to those who may not want to play such a central role. When we asked audiences about increasing participants, some pointed to the social value because ‘normally, I would come to that sort of experience with someone else’ and ‘if you have an experience with other people, you could talk about it afterwards’.

Although *Replica* establishes an intimate three-way relationship between Kim, her replica and the central audience member, it is also possible to add a fourth relationship in the form of ‘witnesses’: these additional audience members watch this powerful experience from an adjacent viewpoint. The first approach was to add more audience members to the stage area wearing VR headsets to share the MR experience. Placed outside the central performance space in a ring, these additional viewers may move around and watch from their own perspective (Figure 8). To achieve this, Ben created a bespoke device synchronisation system that is simpler than more sophisticated multiplayer engines. In this system, a laptop runs a Windows version of *Replica* in a server role. Each Quest headset runs as a client. Using a WiFi or LAN network, the server communicates with clients using UDP/TCP to synchronise starting and playback, so all participants have the same experience, but from their own viewpoint.

Initially, there were concerns that this may make the central audience member uncomfortable, as they were essentially on stage and being watched. However, test audiences reported that others in the space were not too distracting. It was found that having the lighting lower around the outside of the performance area would focus attention in the centre, and that despite the central position seeming more important, some audience members reflected that having a choice in the way that they could participate was useful. The Immersive Experience Economy Network recommends designing for different levels of participation based on their audience research (Barnes, Bucknall and Jacobus, 2024). This is an approach used by immersive theatre makers such as Ferryman Collective who include a variety of audience roles with different levels of interactivity and narrative involvement in their experiences (Lyons and Butchko, 2025).

User testing is underway to explore how the extra audience may influence the artistic and thematic interpretation of the work. Small-scale initial feedback found key words used to describe *Replica* by those witnessing the performance through headsets fall into three main categories linked to its themes: embodied (e.g. movement, close, physical), emotional (e.g. dream, sorrow, fragile) and reflective (e.g. self-connection, soul, shadow). The majority of witnessing audience members would like to experience *Replica* again, split between those who would want the central participant role and those who would be happy with either role. This suggests offering differing levels of participation may increase the repeatability of a performance as well as its accessibility.



Figure 8: Image of the multi-user version tested at Art*VR Festival, Prague. *Image Credit: Christopher Small*

A second approach involved switching from MR (where audiences are required to wear a headset) to Augmented Reality (where content is viewed on screens). This could allow much larger audiences to see the work without a headset. Ben developed an AR camera system that used the same foundations as the MR software but would display the virtual dancer over live camera feeds of the performance area. This system with fixed camera positions was developed as an alternative to casting the view from the central headset, which is very dependent on the audience member's view and prone to excessive movement and bad framing. The potential for this includes viewing *Replica* as a projection, on monitors (for example, left and right of the stage for a seated audience) or for at-home viewing via livestream. The system currently consists of three Microsoft Kinect Azure depth cameras on tripods that are placed in a ring around the performance area. Unity software is used to place *Replica*'s virtual content over the live feeds to create a composite AR view. Camera switching and zooming are possible using this system to cut in real-time from camera to camera, as would be done in a TV studio setting. In addition to the video backgrounds and virtual midground, a depth-sensitive foreground video layer allows the system to display people close to the real camera over the midground virtual content - so that when the real dancer moves in front of the camera, they obscure the virtual content in the midground.

However, despite the increased scope for larger audiences, after several tests Ben and Kerry felt the AR experience lacked some of the intimacy the performance required when seen using passthrough. However, test audience members did report enjoying an early screen casting of the headset view, commenting on the 'extra dimension' of watching both the augmented feed and the live performance, attending to 'the real live dancer's expressions', alongside 'her virtual presence in the space' and 'relationship to the digital'. They felt that most of *Replica*'s subject matter and essence was maintained in terms of the moment of connection, 'staring into the screen', which was 'very moving'. Witnessing without passthrough means that these audience members must see/hear Kim without the mediation of the headset, and when the replica eventually disappears, they shift attention from the screen to the stage for the final moment between performer and participant, bringing focus back to the powerful shared moment of intimate one-to-one connection. This experiential complexity points to the tension that exists between creative intention and interpretive position, suggesting that multiple audience roles in MR need to emerge in parallel with the artistic and technical development to maintain experiential parity across the participatory spectrum.

Conclusions

This article reveals some of the intricacies of developing MR dance project *Replica*. The account evidences the oscillations between artistic and technical decision-making - at times allowing technical constraints to guide judgement (such as the choice to work with the Quest 3 headset), and at others finding unique solutions (such as the unusual inside-out camera rig). During the production process, the team established innovative VolCap and VP performance methodologies

relating to dance; and produced several software solutions, which when developed further, will deliver a unique, tour-ready and emotionally evocative MR live performance.

Overall, the project has been highly successful and productive, receiving international acclaim, and pushing the limits of the technology on a small budget. The lessons learnt from user testing highlight that audiences have much to contribute to interpreting and understanding immersive works, especially in relation to embodied experience, intimacy and connection.

The ongoing and fruitful partnership between Displace Studio and the VIP Studio has been an integral part of *Replica*'s success. Having continued access to the studio and staff has allowed Kerry and Ben to develop the project iteratively over a sustained time period; and to collect audience feedback, respond to user testing, and consider options for scaling. For Displace Studio, this support goes beyond simply having access to cutting-edge equipment and facilities, and it is the relationships that have been built with the staff - who understand the work conceptually, technically and artistically - that have helped shape it; through providing opportunities to share and progress, suggesting technical approaches, and monitoring audience practicalities. They have also prompted the team to consider the financial sustainability of the work for touring, as well as its artistic merits. As independent artists working on a project-by-project funding basis, this ongoing support is crucial.

There are considerable benefits for the VIP Studio also. By pushing at the (still nascent) capabilities of VolCap through its creative application in digital dance performance, Displace Studio brings a wealth of knowledge about the technical pipelines involved, which helps the studio team utilise and understand the hardware and software better. Sharing these solutions opens up creative and technical opportunities for other collaborators. The collaborative model combining academic and creative research in a performance-led approach to R&D is demonstrated by this case as a means to a) secure resources for iterative cycles of performance development through proof-of-concept and prototyping and b) exchange and expand knowledge about the creative potential of these technologies for wider impact.

During the process, new performance and rehearsal processes were developed, including clear skill development for dancer Kim, who evolved new methods for dancing with her (invisible) double, including somatic memory, alongside strategies such as using the VR headset to rehearse by dancing with her virtual counterpart.

A key take-away was the discovery that passthrough can become a medium through which both the live/real elements (including one's own body) and the pre-recorded/virtual content could be perceived as one, in a coherent aesthetic space slightly removed from reality. An audience member related:

The VR headset acted as a conduit through which I was allowed to be very close to the live performer. In this work, the strong connection I felt to both the live and digital Kim came about because my experience was filtered through technological transmission – i.e., the technology allowed me to traverse between worlds in a way that wasn't separate, but which magnified the multifaceted presences of Kim as she became manifest as both live and digital. My experience of the dance was neither live nor digital, but a wonderful commingling of bodies, textures and qualities.

Replica suggests that convincing MR performance is not necessarily achieved through increasingly realistic virtual content. Instead, it emerges through carefully orchestrating multiple integrated media. In addition, rather than removing awareness of the VR headset completely, it may be used as a lens and mask enabling audiences to operate in an immersed, yet slightly distanced and mediated role.

A key immersive sector challenge is how to scale artworks for touring that are made for small audience numbers or require large audiences to all wear headsets. The team's ongoing research addresses this while balancing considerations around maintaining the essence of the artwork and audience experience. As a one-to-one work, *Replica* is a powerful, intimate experience for audiences, and it is important to retain that quality. In terms of the next steps for *Replica*, it will continue to be developed, and Displace Studio are planning a UK tour for 2027.

Beyond the specifics of *Replica*, this article contributes artistic and technical approaches for developing MR performance projects using VolCap and introduces a range of platforms for hybrid engagement for larger audiences. It highlights the benefits of a design-led iterative process that centres user testing, concluding that audiences can offer insightful contributions to understanding digital intimacy. Furthermore, our discussion highlights the opportunities of combining dance and VolCap in MR to evolve concepts of presence, intimacy, authenticity and embodied experience. It emphasises the value of partnerships between independent artists and production facilities in generating an equitable and sustainable creative ecosystem in immersive production.

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