Embodied prototyping in VR: Ideation and bodystorming within a custom VR sandbox

Joshua Robin McVeigh-Schultz
San Francisco State University, San Francisco, United States of America

Elena Márquez Segura
Universidad Carlos III de Madrid, Madrid, Spain

Katherine Isbister
UC Santa Cruz, Santa Cruz, United States of America

Citation

Robin McVeigh-Schultz, J., Márquez Segura, E., and Isbister, K. (2024) Embodied prototyping in VR: Ideation and bodystorming within a custom VR sandbox, in Gray, C., Ciliotta Chehade, E., Hekkert, P., Forlano, L., Ciuccarelli, P., Lloyd, P. (eds.), *DRS2024: Boston*, 23–28 June, Boston, USA. https://doi.org/10.21606/drs.2024.1193

Embodied prototyping in social VR: Ideation and bodystorming in a custom VR sandbox (a case study of visualizing speech)

Joshua McVeigh-Schultz[a,*], Elena Márquez Segura[b], Katherine Isbister[c]

[a]San Francisco State University, School of Design, USA
[b]Universidad Carlos III de Madrid, Dept. of Computer Science and Engineering, USA
[c]University of California Santa Cruz, Dept. of Computational Media, USA

*Corresponding e-mail: jmcvs@sfsu.edu

doi.org/10.21606/drs.2024.1193

Abstract: Social virtual reality platforms present new opportunities for embodied design processes. This paper illustrates a range of embodied design techniques made possible through social engagement with VR/XR technology. Drawing from a case study involving the prototyping of a conversation visualization system for VR meetings, we present several novel embodied design methods in VR (also applicable to XR). These include: new techniques for supporting embodied ideation; new ways of acting out and improvising scenarios together; and new opportunities for preparing and manipulating assets, environments, and low fidelity interactions for embodied design processes. These novel techniques and approaches point to exciting new opportunities for expanding the repertoire of embodied design practice more broadly.

Keywords: embodied design; bodystorming; virtual reality; social VR

1. Introduction

Embodied prototyping is a well-established approach that surfaces design insights through the process of thinking with-and-through the body. Encompassing an ever-expanding repertoire of tactics and techniques, embodied design methods have also evolved considerably over the past three decades, with refinement in areas of: movement, improvisation, contextual enrichment, and working with props. In parallel, embodied design methods have expanded by drawing upon rich intersections with fields of dance, somatics, theater, ethnomethodology, phenomenology, and other fields that engage with embodiment and social context. As the field of embodied design has evolved, practitioners have also frequently drawn upon novel technologies as resources to enhance the sketching, prototyping, and enacting process.

Contributing to this evolution, VR (and XR more broadly) offers new opportunities for innovation in the area of experiential and embodied design methods. Methods like bodystorming or embodied improvisation can be quite different when set in social VR environments. In part, this is due to the strange materiality, physics, and phenomenology of VR (and XR), which can be remarkably alien compared to analogues in the known world. For example, physics in VR and XR offers alternative approaches to movement, gravity, scale, and interaction. Likewise, engagement with virtual assets in VR/XR offers striking differences compared to working with objects in the physical world, as objects can be scaled, duplicated, and repositioned anywhere in space. Moreover, resources such as virtual objects, environments, and interactive features can be prepared, integrated, or adjusted on the fly in ways that would not be possible in physical contexts.

These differences of materiality, physics, and resource-readiness carry powerful significance for experiential prototyping methods. Sharing a VR environment as a creative palette enables different ways of mapping space (and spatial relationships), different ways of sketching experiences, and different opportunities for ad hoc simulations of possible scenarios. In this paper, we use a case study of an in-VR design process to gather initial insights about how this alien phenomenology of VR/XR can support embodied methods in novel ways. These insights point to new forms of embodied ideation (for example, through sketching or bodystorming in/with VR/XR), and to new ways of preparing, arranging, and manipulating assets and environments to support the design process.

1.1 Related work

1.1.1 Experiential design methods: Embodied design as a form of “Sketching”

Experiential and embodied design methods have a long track record in IxD and HCI. Prototyping quick mockups of software design has long been a part of HCI practice (Overmyer, 1991). In the early 2000s, with the anticipation of a far broader range of computationally enabled interactions, the purview of sketching and prototyping methods expanded to address experiential aspects of technological systems (Buxton, 2007).

Subsequently, researchers have developed a wide range of embodied design methods that foreground the value of social movement and improvisation in the design process (Fdili Alaoui et al., 2015; Höök et al., 2018; Loke & Robertson, 2013; Márquez Segura, Turmo Vidal, & Rostami, 2016; Oulasvirta et al., 2003; Schleicher et al., 2010; Wilde et al., 2017). These methods typically focus on engaging the body while designing, e.g. using gestures and other actions as a mode of exploration and reflection (Bekker et al., 1995; Hummels et al., 2007). Some frame embodied design as a form of collaborative “sketching,” or thinking with/through the body along with others (Márquez Segura, Turmo Vidal, Rostami, et al., 2016). So-called ‘bodystorming’ also overlaps with these sorts of design techniques by involving the body and contextual elements in the process of design ideation (Oulasvirta et al., 2003) or to represent scenarios and use cases (Oulasvirta et al., 2003; Schleicher et al., 2010).

Gathered objects and materials have typically played a key role in these sorts of methods. Buchenau and Suri (2000) and other design researchers, such as Sirkin and Ju (2014) and Brandt and Grunnet (2000) point to physical props as useful tools to guide and facilitate embodied improvisation.

Others have drawn on techniques from theatre, such as role-playing and improvisation (Arvola & Artman, 2007; Brandt & Grunnet, 2000; Burns et al., 1994; Mehto et al., 2006; Newell et al., 2006; Sirkin & Ju, 2014; Vines et al., 2014). In some cases, these approaches overlap with more formalized experiential simulations, such as Wizard of Oz (Dahlbäck et al., 1993) techniques, by emphasizing various human-controlled tactics for enacting the actions of computational systems.

1.1.2 Experiential design methods in/for VR/XR and beyond

There is a long history of exploration of prototyping techniques and affordances in VR (Coomans & Oxman, 1996; Dai & Göbel, 1994; Laurel et al., 1994; Moshell et al., 1995; UVa User Interface Group, 1995).

However, while design and research on virtual reality (VR) and its precursor technologies spans nearly half a century, it has only been a mere decade since the first commercial VR headsets expanded access to a much broader set of creators. Along with this recent expansion, practices of VR design methodology have evolved rapidly, both in terms of (i) designing *for* VR as well as (ii) designing *with/in* VR (whether for a VR experience or for some other medium/context).

This paper focuses in particular on the latter (designing with/in VR), and we draw upon related work that approaches VR (and XR more broadly) as a medium for experiential design processes. Existing work has included:

(1) Bodystorming and sketching through virtual reality (Vistisen et al., 2019) and mixed reality (Márquez Segura et al., 2024; Weijdom, 2022; Zhou et al., 2019).

(2) Service prototyping in VR (Boletsis et al., 2017).

(3) Prototyping specialized application domains (Albarrak et al., 2023).

(4) Prototyping and authoring in VR (Stadler et al., 2020; Zhang & Oney, 2020), along with specialized product domains like cars (Zimmermann, 2008), cakes (Mei et al., 2021), and architecture/interior design (Flobak et al., 2019; George et al., 2017).

(5) Mixed reality motion capture for prototyping (Müller et al., 2021).

(6) Collaborative 3D content creation (Chen et al., 2018).

(7) Commercial tools like ShapesXR, Microsoft's Maquette support immersive rapid prototyping within VR.

We draw, in particular, from several research projects have attended closely to the adaptation of experiential design methods for XR. For example, Boletsis et al. (2017) demonstrated how virtual bodystorming and role-play in a collaborative VR environment can support service design processes. They point to VR simulations as a technique that helps bridge the gap between the "actual service environment and its prototype" particularly in contexts that foreground human interaction within a specific spatialized context. Other relevant methods research draws from the legacy of theater includes explorations of performative affordances that combine virtual and physical experience—so called 'frictional realities' of Rostami et al. (2018). Another example is Weijdom's (2022) *performative prototyping* methods for collaborative mixed-reality bodystorming, puppeteering, and performance. Finally, we also draw from embodied speculative techniques such as immersive design fiction which explores speculative social worlds as a form of embodied co-imagining in VR (McVeigh-Schultz et al., 2018a).

1.2 Setting up the case study

This paper focuses on the design processes of a small team designing an application for social VR. Here, rather than evaluate the effectiveness of the design, we aim instead to revisit the project as a case study. We will focus in particular on illustrating the embodied design methods we employed in several design ideation and testing sessions.

Our design team comprised four people, one graduate student designer/developer, one post-doc, and one independent researcher who had become a professor by later design sessions. Two were women and two were men. Ethnic heritage and nationality varied (although all were white presenting). All had at least intermediate experience as VR users.

2. Case study

This case study is based on several design sessions of a small team focused on designing a social VR application that visualized participants' speech over time. The original project goal was to help participants balance their conversational contributions during a VR meeting. Research has demonstrated the value of improving parity in meetings through a range of feedback mechanisms (Woolley et al., 2010), and this project explored similar opportunities in VR. See Fernandes (2020) and Li et al. (2022) for more details about the original project.

Two concepts for supporting conversational parity drove our design process: (1) visualizing speech as a series of colored spheres which spawn while a participant is talking, and (2) a silent moderator agent who subtly intervenes when a participant has spoken too much.

Both of the intervention-concepts were very dynamic in nature and required blocking out of where avatars and items would be in the space and a nuanced sense of timing. There were also questions about how these interventions would integrate in an ambient way into the conversation—being just salient enough, but not overpowering and disruptive. While the concepts evolved over successive prototyping and experiential testing sessions, for this case study write-up we selected two design sessions to illustrate key takeaways from our design process for each of the two concepts.

2.1 Concept 1: Visualizing speech for conversational balance

For Concept 1, we worked with a custom social VR sandbox environment for prototyping a social VR conversation visualization and parity experience. This sandbox approach however only emerged organically as a response to series of challenges. Initially, we drew upon a strong concept (Höök & Löwgren, 2012) from previous experiments involving the spawning of tennis ball sized spheres from speakers' mouths during speech events (McVeigh-Schultz et al., 2018b; McVeigh-Schultz & Isbister, 2021). Our team developed a simple prototype to reproduce this concept in social VR using a combination of Unity with Vive headsets and an integrated Photon User Network (PUN). In an effort to better understand how to best visualize speech in VR meetings, our four-member team conducted a series of testing sessions for each subsequent iteration. These internal tests were treated as in-VR bodystorming session where we could experience the mechanics first-hand and think through the impact of design choices together.

In an initial prototype, we began with a notion of balls the same color as the avatar popping out of the avatar's mouth and piling up to provide an ambient cue of participants' relative amount of speech over time (Figure 1).

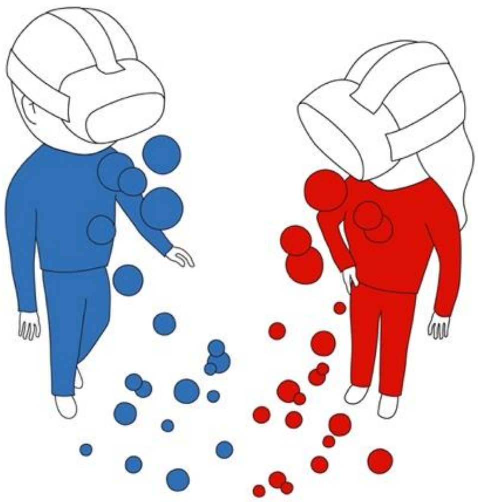

Figure 1 Illustration of two designers testing out initial VR prototype of ball spawning mechanic. Balls would spawn when each speaker spoke, with balls of the corresponding color emerging from the speakers' mouth and falling to the ground.

However, testing out this prototype together in VR, we found the balls fell to the floor and accumulated too haphazardly, rolling around everywhere in the meeting space and making it difficult to use their accumulation as a meaningful indicator of who had spoken more or most recently. This suggested to us that there may be more salient ways to make participants aware of their relative speech over time. As an alternative, we came up with the idea of accumulating the balls into a more specific visualization area. But where should they accumulate so everyone can see them? Up above the table seemed like a good candidate, but how high? And should they persist over time or slowly fade. If the latter, how *soon* should they fade?

Unfortunately, for each question there was a subsequent proposal for a design iteration to test out. And each new iteration demanded software changes which had to be shared and then reloaded onto everyone's machines to jump back into VR. Since each iteration needed to be tested with others (in order to assess its impact on social dynamics), the iterative process was becoming incredibly cumbersome and slowing down our ability to bodystorm in spontaneous ways. Moreover, each new internal test session seemed to surface compounding questions: where on the body should balls be spawning from? How large should the balls be? Should they be connected? How frequent should they spawn? How should balls respond to gravity (if at all)? And, how should we give the participants a sense of cumulative speech in relation to time (both in terms of a single speech event as well as in terms of speech over the course of the entire interaction)? The variables we were considering all felt interdependent and contingent and it was difficult to think about them in isolation.

2.1.1 Using a VR "sandbox" prototype with reconfigurable parameters for bodystorming and embodied improvisation

To address the more nuanced questions described above, we needed a more dynamic and embodied approach to prototyping in VR, one that would allow us to quickly reconfigure and test out alternative design decisions in an ad hoc way. Towards this goal, we developed a custom social VR sandbox for embodied design that allowed balls to spawn from controller positions manually through button presses. This modified social VR prototype enabled a more flexible, "sandbox" system, with multiple options for key interactive design choices that could be calibrated on the fly. For example, attaching the spawn-point of balls to the controllers enabled us to try out positioning the spawn-point in various locations—for instance, locations on the body or in space (see Figure 2). This enabled us to quickly test out how different spawn positions might affect social dynamics, cognitive load, attention, eyelines, and options for ball-accumulation zones. Also, since the system was design to allow us to spawn balls manually using button presses (instead of automatically in response to speech), we were able to simulate a wide range of spawn rates (by Wizard-of-Ozzing these design choices manually on the fly). We could also make decisions about what speech-volume-thresholds should be crossed for a spawn event to occur and explore unique options for how to visualize crosstalk and interruptions.

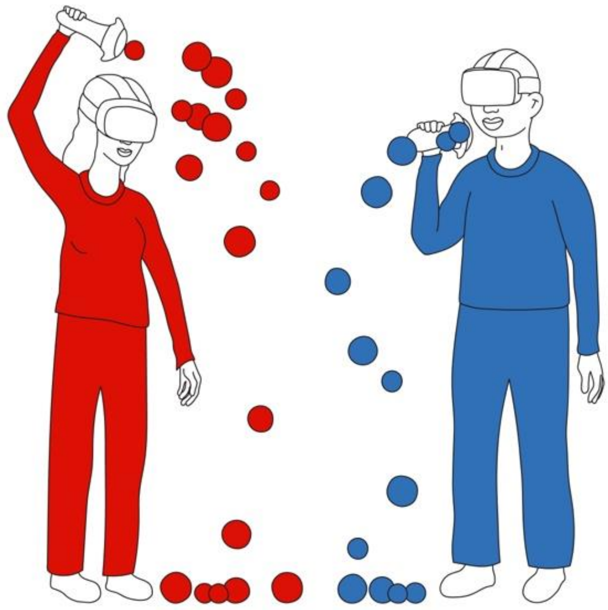

Figure 2 Illustration of two designers manually testing out different spawn positions for speech-triggered ball spawning. In this iteration, balls would spawn from the controllers and fall to the ground.

In addition, we enabled movement up or down on the controller's thumbpad to determine ball size, so that we could change this parameter and test out the social impact on the fly (Figure 3). Using this mechanic we experimented with how ball-size would impact other variables like spawn-position and spawn-rate. We also tested out mapping the diameter of the ball to the duration of a single speech event but ultimately set this option aside so that balls could be observed without obstructing the view of participants when interacting.

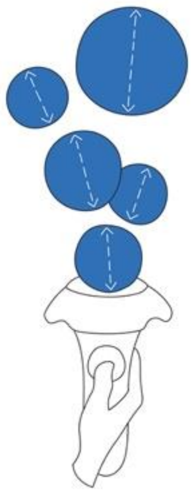

Figure 3 Illustration of a designer manually changing the speech-ball size during a bodystorming session. Moving the thumb up on the track-pad would increase ball-size.

By making these key parameters manually configurable on the fly, we ensured that our in-VR bodystorming sessions could be more fluid, responding to interrelated variables in more intuitive ways that took into account social contingencies as they arose. Bodystorming in a VR prototyping sandbox, for instance, enabled us to play with dynamic parameters and understand their interrelatedness and contingency. With this prototyping sandbox in place, our bodystorming sessions were more productive and enabled us to refine design choices related to the spawn rate, spawn position, and accumulation target, balancing the need to make speech a visually salient social cue (without obstructing eyelines). We ended up with an idea of columns (see Figures 4 and 5) that were table height. We moved from separated columns to a shared column that showed more easily the proportion and interleaving of speech (Figure 5).

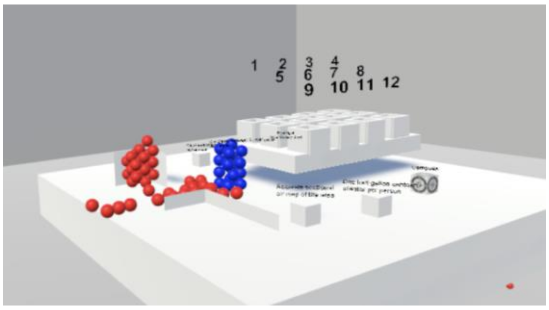

Figure 4 Early dynamic data visualization prototype, built after iterating in our bodystorming environment.

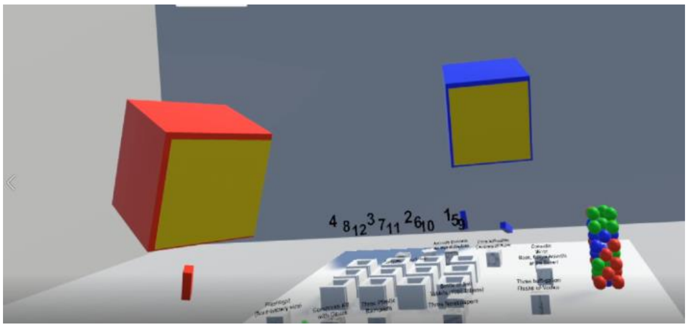

Figure 5 Later version of desert survival task, with participant avatars and conversation visualization (column of balls). Avatars were gathered around the task table.

2.1.2 Using Wizard-of-Oz techniques to visualize individual speech-events alongside cumulative speech

In final design phase, we translated the conversation visualization design into a custom modification of the Mozilla Hubs code base (Figure). In adapting our design this time, we sought to make the duration of individual speech utterances more salient.

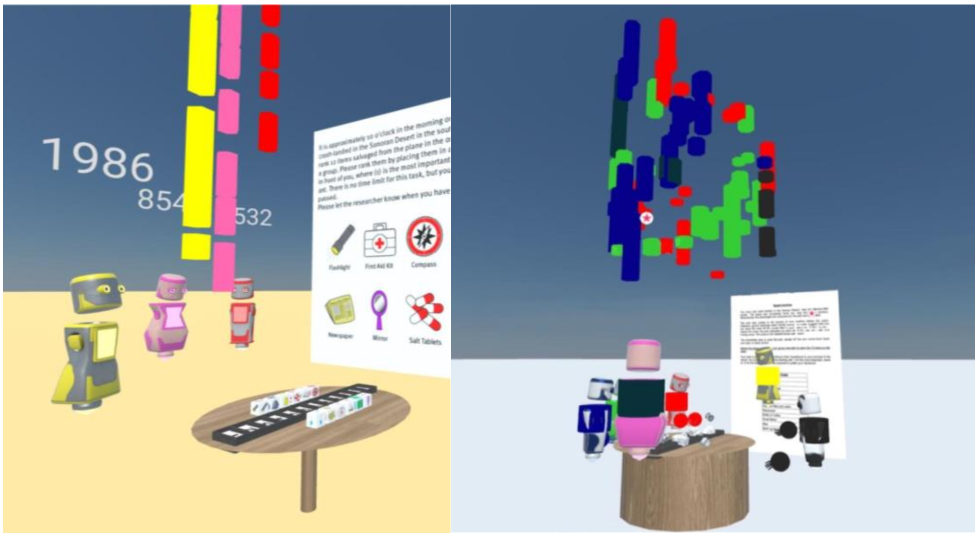

Figure 6 Cylinders visualize the conversation, growing upwards based on each participant's duration of speech.

Again, using a custom VR scene-design tool (Mozilla Spoke) we leveraged Spoke's built in "spawner" features which enabled us to drop interactive 3D objects into the scene that were both grabbable and scalable. Spawning new interactive objects in this way was also available to designers at runtime for models from Sketchfab.

Using this custom social VR environment, we explored the possibility that speech-spheres could increase in size while an avatar was talking. To simulate this experience, we designated one VR participant as a "Wizard of Oz" who would gradually scale-up colored spheres in front of a speaker in real-time.

We found that would be too distracting for long duration speech events that grew quite large. Instead, we utilized the vertical dimension to accommodate elongating multi-colored tubes (Figure) and a "tube system" that gradually moved upward (so that the current speech event was always spawning at the bottom of the system). This approach made the duration of individual speech events salient while also mitigating distracting large-scale/long-duration problems we encountered with expanding spheres.

Later, we shifted to a Hubs Cloud customized code base for development but continued to use embodied prototyping methods in parallel. For example, bodystorming sessions helped us explore relative positioning of tubes (initially to the side of participants but eventually positioned as a "chandelier" that gradually elongates above a round table).

2.2 Concept 2: Intervening agent to support conversation balance

A second concept for balancing participation in VR meetings involved an NPC agent we referred to as "the monster" which could intervene in various ways to make participants aware if someone was dominating the conversation.

We found it was difficult to think and communicate about bodily orientations, eyelines, and inclusion or blocking of participants when we were "acting" as if we were those participants while also trying to position other bodies and props. Hence, we would easily lose referential power when discussing those aspects. How would the monster behave when somebody was talking too much? Would it move towards that person? Would it stay behind that person? Or locate itself in front of them? How would it behave if somebody new started talking? Would it turn to that person, move towards them, or just look at them?

Similar questions surfaced about social proxemics of the meeting participants and where the monster's position during its intervention-state ought to be in relation to the others. We had questions such as: What determines the threshold between intervention and non-intervention state and how should we determine the monster's position and behavior for each state? If the monster comes closer to the one talking the most, how close? How does this affect their line of sight to the others in the conversation? People need to see the monster, but it shouldn't be in the middle of the participants (which would be foregrounding it all the time). So, we decided to try having it move around the periphery, gradually get closer and look at the speaker, and finally turn the color of someone when they were talking too long. This approach created new challenges though in terms of calibrating how far from the group (when in background) and how close to the speaker (when in foreground) and whether to have cues of gaze and color be driven by current speaker vs. accumulated longest speaker. Moreover, we weren't sure whether movement from background to foreground should be triggered by duration of a single speech event (a longwinded comment for ex) or by the cumulative dominance of a single participant over time. Multiple iterations to experiment with dynamics like these was cumbersome with the tool we had chosen (Unity shared code environment with Photon User Network) and required us all to reload each time and often troubleshoot bugs and other performance-related glitches that took time to solve.

2.2.1 Preparing the VR sandbox

To better address the questions and design challenges above, we prepared a social VR environment with a range of preprepared interactable virtual assets that we could use to 'bodystorm' in VR. This time we aimed to represent ourselves and other objects through miniaturized tokens (i.e. virtual assets including: possible agent—"monster"—bodies, avatar bodies, and objects that might spawn to form a visualization of conversation balance and time spent). We created small scale proxies of the VR participants and "monster" which we could rescale and reposition. We also created a range of primitives of different dimensions (cuboid and capsule shaped objects from Unity) which we recombined to communicate scale-model elements such as a table. We also decided that virtual assets gathered in our sandbox environment should not have regular physics and gravity but should rather be repositionable as static objects in space. This set-up enabled us to propose and experiment with various approaches to social proxemics and eyelines (as described below).

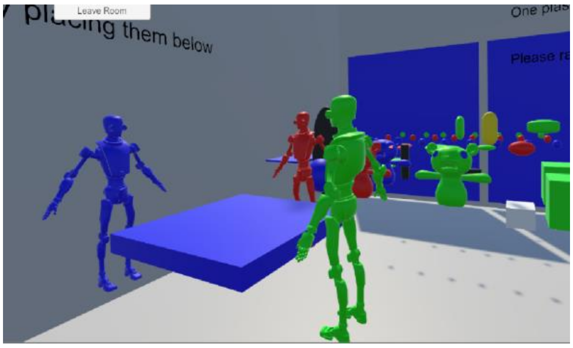

Figure 6 Bodystorming environment with placeholder avatars, agents, and primitive shapes for use representing data visualization elements.

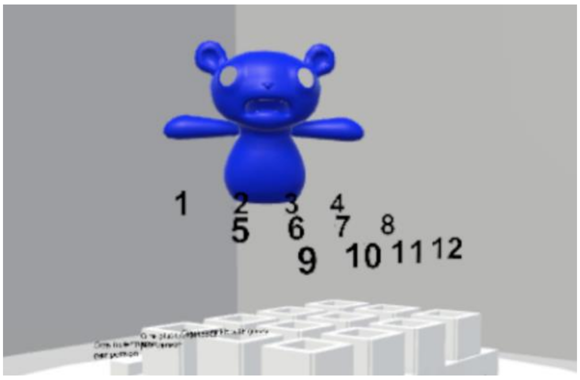

Figure 7 Early agent prototype for the conversation balance project, using ready-to-hand 3D asset.

2.2.2 Using an in-VR prototyping "sandbox" with props to explore proxemics and behavior for an ambient agent ("monster")

Doing bodystorming within the VR sandbox described above helped us to explore how to create enough appropriate social signaling (gaze direction, interpersonal space) so that the monster could be positioned socially and make clear who might be dominating (or dropping out of) the conversation. Manipulating avatars and NPC at this smaller "doll scale" gave us an overhead view over a shared "play space" and enabled us to treat the various objects in-play as shared resources for 'collaborative imagining' (Murphy, 2005). In other words, the various positioning of dolls and other virtual assets relative to one another in response to hypothetical social scenarios enabled us to externalize the mechanics of the monster and its various options for both ambient and intervention modes with nuance that otherwise would have remained tacit. In addition, altering avatar scale on the fly enabled us to explore an alternative mechanic of changing the scale of avatars in relation to speech—either shrinking or growing in response to speech over time.

2.3 Key takeaways from the design process

2.3.1 New ways of Preparing and Manipulating the Environment for Embodied Design

For both concepts, challenges with our initial prototypes led to a preparatory design process in which we decided as a team what kind of features a social VR sandbox would need to enable us to do successful bodystorming together in VR. The design team also found it extremely useful to gather a set of virtual materials with lo-fi configurable interactive features to support ad hoc adjustments during embodied design. Having these materials ready-to-hand within the VR context helped to both explain and try out ideas. By preparing our sandboxes with modular interactive features and unusual properties of physics and scale, we were able to refine and calibrate design choices on the fly in ways that would have been cumbersome—if not impossible—in a more traditional bodystorm rooted in the physical world.

2.3.2 New Ways of Ideating and Acting It Out in VR/XR

The team jumped into social VR to discuss ideas for the interventions and for the experimental task frequently, throughout the design process. This helped keep the constraints and opportunity space of VR ready-to-mind, and allowed designers to illustrate ideas using the assembled props.

Using Concept 1's VR "sandbox" environment, we used a so-called "Wizard of Oz" approach to drive interactive mechanics and puppeteer virtual proxies by piloting these elements ourselves (e.g. spawning and "tossing" balls at the right timing, or moving the 'monster' NPC around in space to simulate its reactions to others' conversation). For Concept 2, working at "dollhouse" scale enabled us to operate these Wizard of Oz mechanics together in an ad hoc and hands-on way. This helped refine our thinking about issues such as timing and spatial constraints described above. Similarly, for Concept 1, we simulated conversation together while assigning one person to "Wizard of Oz" different speech-ball rates, size, spawn points, and accumulation zones. In these ways, we were able to tinker together with the way speech could be visualized and calibrate—and reflect on—the salience of this feature on the fly.

For Concept 2, the prospective (re)positioning and talking through of various social contingencies together enabled us to have a richer conversation about the architecture of space, dynamics of social proxemics, and geometries of eyelines. By working with scale-model proxies for avatars, NPCs, and other virtual objects, we were able to jump to a 3rd person "dollhouse" view to manipulate, scale, and reposition the arrangement of proxy avatars, NPCs and other assets. Talking through these dynamics in relation to various social scenarios helped us work through details such as how interpersonal spacings might work and enabled us to add nuance to questions of how/whether/and in what contexts the "monster" would fade into foreground or recede into the background.

3. Discussion

The approaches we have presented thus far take advantage of the unique ways that VR (and XR more broadly) afford interactions that depart from what is possible or convenient in the physical world. Experiences that would otherwise be costly to simulate can be easily created in VR. Moreover, experiences that would not be possible in the physical world — such as Alice-in-Wonderland-style shrinking or expanding — are easily managed in VR. Reviewing the case study's multiple design sessions, we detail below, with more specificity, the particular techniques and themes we believe can be useful to others going forward.

3.1 Embodied ideation in VR/XR

At a basic level, differences in physics, materiality, and interactive affordances make different kinds of embodied design processes possible. Designers can utilize alternative rules of physics, for example, objects without gravity or momentum that can be positioned anywhere during embodied sketching and bodystorming sessions. Moreover, designers can manipulate such objects in real time to improvise the behavior of interactive systems or agents. These alternative physics also enable fluid movement between different experiential scales (for example, manipulating assets at "dollhouse" scale). Interactive features can themselves become a resource for embodied sketching, bodystorming, and improvisation (as when a custom ball-spawn trigger was created so that designers could test out various contexts and frequencies of ball-spawning during speech).

3.2 Preparing the environment for embodied design in VR/XR

3.2.1 Metadesign for embodied design in VR

Due to the wide range of possible affordances in VR, some of the most important early design decisions involve making choices about the specific application, environment, and resources to be utilized for in-world ideation. This adds a layer of abstraction to the early design process insofar as designers need to consider the specific application, virtual environment, affordances, assets, and other resources to support effective exploration. In the physical world, designers rarely start by redesigning the whiteboard or the sticky note prior to beginning the design process, and while embodied design methods like experience prototyping might involve gathering props or crafting environments as design resources, abstract concepts like physics and basic affordances of material objects don't need to be considered in the same way they do in VR. This process of recursively designing VR environments for collaborative design process is one that we've come to refer to as 'meta-design' in VR.[1] Metadesign, here, denotes 'designing an interactive system which will later be used to support embodied design processes.' This preparatory design step includes decisions, for example,

---

[1] Note: the term 'metadesign' has a much more specific meaning in the context of the French social history of design as described in Busbea (Busbea, 2009), however, here we are using the term in a more colloquial sense as preparatory design to support a subsequent design process.

about what out-of-the box tools or semi-authorable environments best support the kind of embodied exploration needed for a particular design goal.

3.2.2 Dollhousing

We have described “dollhousing” as the process of arranging and manipulating prepared assets at different scales in order to explore and externalize design choices related to, for instance: environmental layout, proxemics, and theatrical blocking. Manipulating environmental assets at smaller scales can be particularly valuable as a way of doing environmental design. Moreover, doing this sort of design process as a collaborative process allows for team members to build on one another’s ideas and discover novel perspectives that one might not arrive at on their own.

3.2.3 Virtual bricolage

In VR/XR the cost of gathering virtual props, constructing environments, and mocking up interactive simulations in a shared world is strikingly low. Here, bringing in 3D models found via online repositories of free models serves as the “dollar store” equivalent of finding props to use as resources for experiential prototyping. Meta-design preparation can often involve this kind of virtual resource gathering and environmental positioning as preparation for bodystorming and dollhousing in VR. We have come to refer to the arrangement and repurposing of 3D assets for embodied design as ‘virtual bricolage.’

3.3 Future work

While we focused here on embodied ideation and bodystorming in VR as a mode of experiential prototyping, a broader range of improvisational and theatrical methods and techniques could have been explored, and there are likely opportunities for future contribution in this area. Venues such as conference workshops would be ideal for bringing together the larger community of experiential designers who do embodied design work using VR/XR tools. The broader discussion of embodied methods in XR could benefit from practitioners in adjacent fields such as architecture, interior design, theater, etc. What sorts of VR sandbox features might be most useful in these broader contexts? Where might we need to innovate new toolsets, and where could we adapt existing ones?

4. Conclusion

In this paper, we have presented a case study illustrating how social virtual reality environments can be particularly well suited to supporting embodied design processes. We have also articulated a set of approaches that can be used to enhance the embodied design process, including: (1) techniques for embodied ideation in/through VR during bodystorming; (2) meta-design considerations for preparing a VR environment for embodied design (including preparing props, designing sandbox environments, and customizing affordances; (3) virtual bricolage techniques that leverage the availability of readily available 3D models, prefabricated environments, and other virtual assets as fodder for remixing in VR; and (4) "dollhouse" manipulations of scale to explore layout, proxemics, and theatrical blocking. These new ways of working represent—we feel—new, exciting possibilities for embodied ideation, bodystorming, and improvisation and ultimately represent a new mode of thinking in-and-through VR/XR together.

Despite the often-cumbersome nature of setting up shared VR prototyping environments from a technical and user experience perspective, we have come to love social VR as a medium that can support embodied ideation. VR-based prototyping techniques like the ones we have outlined in this paper may help us as researchers and practitioners to more fluidly envision and anticipate both what is possible and perhaps more importantly, what may be desirable (or not) from an embodied perspective. Some in the broader design communities may find VR experiences to be disembodied, alienating, and strange, and posit that this means they will forever be niche experiences. But we instead embrace the strangeness of VR (see for example, McVeigh-Schultz & Isbister, 2021) as a productive resource that can support new ways of designing together and lead to valuable insights not always possible with more traditional tools. We hope this paper will be of value not only for designers working in VR, but also to the design community at large, who may subsequently consider using VR as a prototyping resource to support design for other application spaces both digital and physical.

Acknowledgements: This material is based upon work supported by the National Science Foundation under Grant No. 2007627 and No. 2007755. In addition, early research exploration that seeded this work was funded in part by Mozilla. Special recognition to Sean Fernandes, whose design and development work for his MA thesis in Katherine Isbister's lab played a key role in this paper. Special thanks also to Max Kreminski, whose development work adapting Mozilla Hubs led to a refinement of the conversation balance tool, and to Victor Li, whose MA thesis focused on this refined iteration in Hubs. Special recognition to Scott Fisher and his Mobile and Environmental Media Lab at USC, where Max Kreminski and McVeigh-Schultz collaborated on a prototype that went on lay the groundwork for the VR conversation visualization techniques developed later at UCSC by Fernandes. Also, special acknowledgement to Ella Dagan for her work on conversation balancing through the Lågom project in Isbister's lab which helped inspire this work.

6. References

Albarrak, L., Metatla, O., & Roudaut, A. (2023). Using Virtual Reality and Co-Design to Study the Design of Large-scale Shape-Changing Interfaces. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, 1–17. https://doi.org/10.1145/3544548.3581144

Arvola, M., & Artman, H. (2007). Enactments in Interaction Design: How Designers Make Sketches Behave. *Artifact*, *1*(2), 106–119. https://doi.org/10.1080/17493460601117272

Bekker, M. M., Olson, J. S., & Olson, G. M. (1995). Analysis of gestures in face-to-face design teams provides guidance for how to use groupware in design. *Proceedings of the 1st Conference on Designing Interactive Systems: Processes, Practices, Methods, & Techniques*, 157–166. https://doi.org/10.1145/225434.225452

Boletsis, C., Karahasanovic, A., & Fjuk, A. (2017). Virtual Bodystorming: Utilizing Virtual Reality for Prototyping in Service Design. In L. T. De Paolis, P. Bourdot, & A. Mongelli (Eds.), *Augmented Reality, Virtual Reality, and Computer Graphics* (Vol. 10324, pp. 279–288). Springer International Publishing. https://doi.org/10.1007/978-3-319-60922-5_22

Brandt, E., & Grunnet, C. (2000). Evoking the future: Drama and props in user centered design. *PDC*, 11–20.

Buchenau, M., & Suri, J. F. (2000). Experience Prototyping. *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, 424–433. https://doi.org/10.1145/347642.347802

Burns, C., Dishman, E., Verplank, W., & Lassiter, B. (1994). Actors, Hairdos & Videotape—Informance Design. *Conference Companion on Human Factors in Computing Systems*, 119–120. https://doi.org/10.1145/259963.260102

Busbea, L. (2009). Metadesign: Object and environment in France, c. 1970. *Design Issues*, *25*(4), 103–119.

Buxton, B. (2007). *Sketching user experiences: Getting the design right and the right design* (Nachdr.). Morgan Kaufmann.

Chen, C.-W., Peng, J.-W., Kuo, C.-M., Hu, M.-C., & Tseng, Y.-C. (2018). Ontlus: 3D Content Collaborative Creation via Virtual Reality. In K. Schoeffmann, T. H. Chalidabhongse, C. W. Ngo, S. Aramvith, N. E. O'Connor, Y.-S. Ho, M. Gabbouj, & A. Elgammal (Eds.), *MultiMedia Modeling* (Vol. 10705, pp. 386–389). Springer International Publishing. https://doi.org/10.1007/978-3-319-73600-6_38

Coomans, M. K. D., & Oxman, R. M. (1996). Prototyping of Designs in Virtual Reality. *Proceedings of the 3rd Conference on Design and Decision Support Systems in Architecture and Urban Planning*.

Dahlbäck, N., Jönsson, A., & Ahrenberg, L. (1993). Wizard of Oz Studies: Why and How. *Proceedings of the 1st International Conference on Intelligent User Interfaces*, 193–200. https://doi.org/10.1145/169891.169968

Dai, F., & Göbel, M. (1994). Virtual Prototyping: An Approach Using VR-Techniques. *ASME 1994 International Computers in Engineering Conference and Exhibition*, 311–316. https://doi.org/10.1115/CIE1994-0414

Fdili Alaoui, S., Schiphorst, T., Cuykendall, S., Carlson, K., Studd, K., & Bradley, K. (2015). Strategies for Embodied Design: The Value and Challenges of Observing Movement. *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*, 121–130. https://doi.org/10.1145/2757226.2757238

Fernandes, S. (2020). *SUPPORTING COLLABORATION IN SOCIAL VR* [UC Santa Cruz]. https://escholarship.org/uc/item/7f30q6dn

Flobak, E., Wake, J. D., Vindenes, J., Kahlon, S., Nordgreen, T., & Guribye, F. (2019). Participatory Design of VR Scenarios for Exposure Therapy. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3290605.3300799

George, B. H., Sleipness, O. R., & Quebbeman, A. (2017). *Using Virtual Reality as a Design Input: Impacts on Collaboration in a University Design Studio Setting*. Wichmann Verlag. https://doi.org/10.14627/537629026

Höök, K., Caramiaux, B., Erkut, C., Forlizzi, J., Hajinejad, N., Haller, M., Hummels, C. C. M., Isbister, K., Jonsson, M., Khut, G., Loke, L., Lottridge, D., Marti, P., Melcer, E., Müller, F. F., Petersen, M. G., Schiphorst, T., Márquez Segura, E., Ståhl, A., … Tobiasson, H. (2018). Embracing First-Person Perspectives in Soma-Based Design. *Informatics*, *5*(1), 8. https://doi.org/10.3390/informatics5010008

Höök, K., & Löwgren, J. (2012). Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Transactions on Computer-Human Interaction*, *19*(3), 1–18. https://doi.org/10.1145/2362364.2362371

Hummels, C., Overbeeke, K. C., & Klooster, S. (2007). Move to Get Moved: A Search for Methods, Tools and Knowledge to Design for Expressive and Rich Movement-based Interaction. *Personal Ubiquitous Comput.*, *11*(8), 677–690. https://doi.org/10.1007/s00779-006-0135-y

Laurel, B., Strickland, R., & Tow, R. (1994). Placeholder: Landscape and narrative in virtual environments. *ACM SIGGRAPH Computer Graphics*, *28*(2), 118–126. https://doi.org/10.1145/178951.178967

Li, J. V., Kreminski, M., Fernandes, S. M., Osborne, A., McVeigh-Schultz, J., & Isbister, K. (2022). Conversation Balance: A Shared VR Visualization to Support Turn-taking in Meetings. *CHI Conference on Human Factors in Computing Systems Extended Abstracts*, 1–4. https://doi.org/10.1145/3491101.3519879

Loke, L., & Robertson, T. (2013). Moving and Making Strange: An Embodied Approach to Movement-based Interaction Design. *ACM Trans. Comput.-Hum. Interact.*, *20*(1), 7:1-7:25. https://doi.org/10.1145/2442106.2442113

Márquez Segura, E., Turmo Vidal, L., & Rostami, A. (2016). Bodystorming for movement-based interaction design. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *12*(2), 193–251. http://dx.doi.org/10.17011/ht/urn.201611174655

Márquez Segura, E., Turmo Vidal, L., Rostami, A., & Waern, A. (2016). Embodied Sketching. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 6014–6027. https://doi.org/10.1145/2858036.2858486

Márquez Segura, E., Vega Cebrián, J. M., Maldonado, A., Cristóbal, L., & Bellucci, A. (2024). Embodied Hybrid Bodystorming to Design an XR Suture Training Experience. *Proceedings of the TEI Conference*.

McVeigh-Schultz, J., & Isbister, K. (2021). The Case for “Weird Social” in VR/XR: A Vision of Social Superpowers Beyond Meatspace. *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–10. https://doi.org/10.1145/3411763.3450377

McVeigh-Schultz, J., Kreminski, M., Prasad, K., Hoberman, P., & Fisher, S. S. (2018a). Immersive Design Fiction: Using VR to Prototype Speculative Interfaces and Interaction Rituals within a Virtual Storyworld. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS ’18*, 817–829. https://doi.org/10.1145/3196709.3196793

McVeigh-Schultz, J., Kreminski, M., Prasad, K., Hoberman, P., & Fisher, S. S. (2018b). Immersive Design Fiction: Using VR to Prototype Speculative Interfaces and Interaction Rituals within a Virtual Storyworld. *Proceedings of the 2018 Designing Interactive Systems Conference*, 817–829. https://doi.org/10.1145/3196709.3196793

Mehto, K., Kantola, V., Tiitta, S., & Kankainen, T. (2006). Interacting with user data – Theory and examples of drama and dramaturgy as methods of exploration and evaluation in user-centered design. *Interacting with Computers*, *18*(5), 977–995. https://doi.org/10.1016/j.intcom.2006.05.006

Mei, Y., Li, J., de Ridder, H., & Cesar, P. (2021). CakeVR: A Social Virtual Reality (VR) Tool for Co-designing Cakes. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–14. https://doi.org/10.1145/3411764.3445503

Moshell, J. M., Cortes, A., Clarke, T., Abel, K. C., Kilby, M., Lisle, C. R., Mapes, D. P., & Morie, J. F. (1995). Research in Virtual Environments and Simulation at the Institute for Simulation and Training of the University of Central Florida. *Presence: Teleoperators and Virtual Environments*, *4*(2), 209–217. https://doi.org/10.1162/pres.1995.4.2.209

Müller, L., Pfeuffer, K., Gugenheimer, J., Pfleging, B., Prange, S., & Alt, F. (2021). SpatialProto: Exploring Real-World Motion Captures for Rapid Prototyping of Interactive Mixed Reality. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–13. https://doi.org/10.1145/3411764.3445560

Murphy, K. M. (2005). Collaborative imagining: The interactive use of gestures, talk, and graphic representation in architectural practice. *Semiotica*, *2005*(156). https://doi.org/10.1515/semi.2005.2005.156.113

Newell, A. F., Carmichael, A., Morgan, M., & Dickinson, A. (2006). The use of theatre in requirements gathering and usability studies. *Interacting with Computers*, *18*(5), 996–1011. https://doi.org/10.1016/j.intcom.2006.05.003

Oulasvirta, A., Kurvinen, E., & Kankainen, T. (2003). Understanding Contexts by Being There: Case Studies in Bodystorming. *Personal Ubiquitous Comput.*, *7*(2), 125–134. https://doi.org/10.1007/s00779-003-0238-7

Overmyer, S. P. (1991). Revolutionary vs. Evolutionary rapid prototyping: Balancing software productivity and HCI design concerns. *Proceedings of the 4th International Conference on Human-Computer Interaction*, 303–308.

Rostami, A., Rossitto, C., & Waern, A. (2018). Frictional Realities: Enabling Immersion in Mixed-Reality Performances. *Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video*, 15–27. https://doi.org/10.1145/3210825.3210827

Schleicher, D., Jones, P., & Kachur, O. (2010). Bodystorming As Embodied Designing. *Interactions*, *17*(6), 47–51. https://doi.org/10.1145/1865245.1865256

Sirkin, D., & Ju, W. (2014). Using Embodied Design Improvisation as a Design Research Tool. *International Conference on Human Behavior in Design*, *October*, 1–7.

Stadler, S., Cornet, H., Mazeas, D., Chardonnet, J.-R., & Frenkler, F. (2020). IMPRO: IMMERSIVE PROTOTYPING IN VIRTUAL ENVIRONMENTS FOR INDUSTRIAL DESIGNERS. *Proceedings of the Design Society: DESIGN Conference*, *1*, 1375–1384. https://doi.org/10.1017/dsd.2020.81

UVa User Interface Group. (1995). Alice: Rapid prototyping for virtual reality. *IEEE Computer Graphics and Applications*, *15*(3), 8–11. https://doi.org/10.1109/38.376600

Vines, J., Denman-Cleaver, T., Dunphy, P., Wright, P., & Olivier, P. (2014). Experience Design Theatre: Exploring the Role of Live Theatre in Scaffolding Design Dialogues. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 683–692. https://doi.org/10.1145/2556288.2556960

Vistisen, P., Luciani, D., & Ekströmer, P. (2019). *Sketching Immersive Information Spaces: Lessons learned from experiments in 'sketching for and through virtual reality.'* 25–36.

Weijdom, J. (2022). Performative prototyping in collaborative mixed reality environments: An embodied design method for ideation and development in virtual reality. *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*, 1–13. https://doi.org/10.1145/3490149.3501316

Wilde, D., Vallgårda, A., & Tomico, O. (2017). Embodied Design Ideation Methods: Analysing the Power of Estrangement. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5158–5170. https://doi.org/10.1145/3025453.3025873

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010). Evidence for a Collective Intelligence Factor in the Performance of Human Groups. *Science*, *330*(6004), 686–688. https://doi.org/10.1126/science.1193147

Zhang, L., & Oney, S. (2020). FlowMatic: An Immersive Authoring Tool for Creating Interactive Scenes in Virtual Reality. *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology*, 342–353. https://doi.org/10.1145/3379337.3415824

Zhou, Z., Márquez Segura, E., Duval, J., John, M., & Isbister, K. (2019). Astaire: A Collaborative Mixed Reality Dance Game for Collocated Players. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 5–18. https://doi.org/10.1145/3311350.3347152

Zimmermann, P. (2008). Virtual Reality Aided Design. A survey of the use of VR in automotive industry. In D. Talaba & A. Amditis (Eds.), *Product Engineering: Tools and Methods Based on Virtual Reality* (pp. 277–296). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8200-9_13

About the Authors:

Joshua McVeigh-Schultz is Assistant Professor of Design at San Francisco State University. His research sits at the intersection of speculative and experiential design, with publication topics spanning: social XR, immersive design fiction, speculative ritual design, and affordance theory.

Elena Márquez Segura is a Beatriz Galindo Distinguished Researcher at UC3M doing design research at the intersection of HCI, Interaction Design, and Games & Play, focused on embodied design methods to support design, and on technology-supported experiences for physical and social action.

Katherine Isbister is the Jack Baskin Endowed Chair in Engineering at UC Santa Cruz. Her research team creates interactive experiences at the intersection of HCI and Games/Play to heighten social and emotional connections and wellbeing, with over 100 peer-reviewed publications.