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Reference:

Olthof Anne Marleen, Verlinden Jouke, Allouch Somava Ben.- Exploration of design methods and tools for virtual, augmented and mixed reality
2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), 17-21 October, 2022, Singapore- ISSN 2771-1102 - IEEE,
2022, p. 233-237
Full text (Publisher's DOI): <https://doi.org/10.1109/ISMAR-ADJUNCT57072.2022.00052>
To cite this reference: <https://hdl.handle.net/10067/1933070151162165141>

Exploration of design methods and tools for virtual, augmented and mixed reality

Anne Marleen Olthof*
Amsterdam University of
Applied Sciences
University of Amsterdam

Jouke Verlinden†
University of Antwerp

Somaya Ben Allouch‡
University of Amsterdam

ABSTRACT

This paper shows an overview of design practices of the XR-lab at the Amsterdam University of Applied Sciences, The Netherlands. Over the course of six years, interdisciplinary teams of students have delivered 55+ prototypes in virtual, augmented, and mixed reality for a variety of 40+ clients. As human-computer interaction is entering a new evolutionary phase towards human-computer integration, new opportunities in extended reality (XR) have the potential to fundamentally alter human characteristics and abilities. Therefore, this paper begins with taking a philosophical stance on 'being human' and the anthropological concept of 'liminality' in XR-experiences. A further exploration of the concept of 'emotional rehearsal spaces' uses know-how from performance art, dance, architecture, and dramaturgy. Insights from tangible practices at the XR-lab show the cultural journey in XR-collaborations. This is made visible through a quick and dirty experiment on artistic thinking, design thinking, and system thinking, which shows how interdisciplinary collaborations are able to ignite new combinations of thought in design teams and individual professionals. Finally, we show an overview of specific design methods and tools that have been explored at the XR-lab over the years.

Keywords: Exploration, design methods, design tools, human enhancement, extended reality, mixed reality, augmented reality, virtual reality

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Human-centered computing—Interaction design—Interaction design theory, concepts and paradigms

1 INTRODUCTION

In the growing prevalence of pervasive digital technology into our daily lives, we see the emergence of computing systems that can sense, interpret, and automatically act on body-based signals, giving 'the system the opportunity to act on the experience alongside the user without needing user input' [1]. Although the concept of human-computer integration has been known for decades [11] it is only now entering a new evolutionary phase, which leads to a paradigm shift in the field of Human-Computer Interaction (HCI), from interaction to the integration of computing devices with the human body [7]. Human-centered design (HCD) - the leading approach for design in HCI - will not be sufficient anymore as we need to shift the focus away from the question 'how do we interact with systems?' towards 'how are humans and systems integrated?' [15]. Since 2016, the XR-lab at Amsterdam University of Applied Sciences is exploring extended reality in an interdisciplinary community of practice wherein a blend of students, teachers, researchers, and industry part-

ners collaborate and explore ideas with emerging technologies and computational mediated interaction. Student design teams consist of artistic thinkers, design thinkers and system thinkers, such as fashion designers, product designers, interaction designers, architects, software engineers and game developers. Over the years, the XR-lab has delivered 55+ prototypes of VR/AR/MR experiences for training, entertainment, fashion, cultural representations, diagnostic tools, using a variety of methods and tools in the design process. Section 2 explains a philosophical stance on 'being human' and explores 'liminality' in human enhancement XR. In section 3 is shown what we can learn from performative art, dance, architecture, and dramaturgy for envisioning XR emotional rehearsal spaces. Section 4 unfolds the cultural journey in XR collaborations. In section 5, an overview of design methods and tools in the XR-lab's projects is shown. Concluding remarks are made in the final section of this paper.

2 A PHILOSOPHICAL STANCE ON 'BEING HUMAN' IN XR

The XR-lab's philosophical stance is described through (2.1) reality realms and (2.2) the concept of 'liminality' in human enhancement XR.

2.1 Reality Realms

The virtuality continuum, defined by Milgram and Kishinos [14], relates to 'the mixture of classes of objects presented in any particular display situation', from real environments to virtual environments. In figure 1, the Real environment on the left exemplifies a world without digital displays. Further to the right a multi-layered reality within an existing reality is shown, Augmented Reality (AR), providing an add-on to Real environments. In the ideal setting, AR fluently integrates into the Real environment, making sure that human cognition and perception is not disturbed by it. Further integration of the human body in a virtual reality environment can be established by Augmented Virtuality (AV), which captures real-world content (such as smell and taste) and brings that content into VR. Virtual Reality (VR) is usually called an 'experience', which is artificially created without capturing any content from the Real environment. Mixed reality is a blend of physical and digital worlds, unlocking natural and intuitive 3D, human, computer, and environmental interactions.

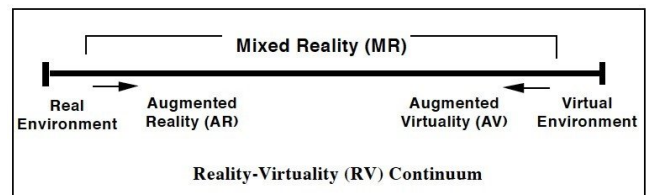


Figure 1: The virtuality continuum from [14]

2.2 The concept of 'liminality' in human enhancement XR

In Anthropology, the ambiguous intermediary stage of initiation rites is called the 'liminal stage' [8], as it removes participants from previous limits and guides them towards the formation of new rules.

*e-mail: a.m.olthof@hva.nl

†e-mail: jouke.verlinden@uantwerpen.be

‡e-mail: s.ben.allouch@hva.nl

Each time we put on a head-mounted display (HMD), we are immersing ourselves into the virtuality continuum. This can lead as well to a (temporal or permanent) change of identity and dynamic feelings of ambiguity. The experience of being in the ‘betwixt and between’ [19] of realities without having a clearly defined status or identity can be confronting, conflicting and controversial. As HCI is entering a new evolutionary phase, new opportunities arise that have the potential to fundamentally alter human characteristics and abilities. This post-humanistic reality [5] has the potential to question, collapse, or even eliminate traditional perspectives on what it means to be a ‘human being’. In philosophical anthropology, humans are seen as biologically imperfect or incomplete beings who must consequently ‘shape and develop’ [18] themselves. In this light, we can argue that every project that makes use of XR-technology explores how human species move from one form of ‘being incomplete’ to another form of being incomplete. XR-technology can facilitate exploratory research and support the search for new meanings of ‘being human’ in post-humanistic realities. One inspiring example of this is the research done by Brenda Laurel in the 90s. Brenda Laurel [10] explored computer games for 12-years old girls, who were in the midst of transitioning to becoming adolescent. Her research led to the insight that what girls were really asking for was ‘emotional rehearsal space’ to navigate emotionally through a social landscape and exercise the love of social complexity and narrative intelligence [4]. This example shows that XR-projects can be seen as emotional rehearsal spaces wherein we explore what happens when we are being removed from existing psycho-physical limits and are transcending from known classifications to unknown classifications of ‘being human’ [16].

3 ENVISIONING EMOTIONAL REHEARSAL SPACES IN XR

The ‘liminal’ stage that occurs when moving from one form of ‘being incomplete’ to another form of being incomplete requires further understanding in how human beings connect and express themselves in the virtuality continuum. Therefore, we study the human-technology relationship when stages of liminality in human enhancement are being encountered. This can be done by studying and exploring practices through the lenses of performance art, dance, architecture, and dramaturgy.

3.1 Performative and In-bodied Space, Movement and Time

The shaping of the emotional experience is critical to the development of any dramatic experience, whether in a theater or through a computer-mediated interaction. Dramatic experiences demand full body awareness to let actors respond effortlessly in the moment. Good actors have learned how to breathe amidst the chaos of performing. The creation of this energetic space can be supported by using *performative* techniques and a *phenomenological* approach which softly plays with strict and liminal boundaries of the human body. Many people experience a form of stress when they enter XR-prototypes. The digital-physical enhancements of a human body can lead to isolated experiences in XR which are built of fight-flight-freeze responses, instead of engaging with the physiological and psycho-immunological systems in the human body. The use of dance approaches - such as Biodanza [17] - can stimulate auto-regulation of the human body and integrate personal, interpersonal and transcendental levels. Laban Movement Analysis [6], a system of dance notation, indicates the aesthetics of movement and can support the exploration of physical diversity through analyzing movement. Our emotional experience is formed by resonating our inner bodies with XR-stimuli that are being radiated to the human body. This dynamical process is accommodated by the inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant in XR.

3.2 Architectural and Dramaturgical Space, Movement and Time

Emotional rehearsal spaces in XR can explore a ‘third body relationship’ that unfolds in-between the human body and the XR-experience. The ‘third body relationship’ takes shape when exteroceptive and interoceptive qualities of human interaction in XR are balanced. These qualities can be envisioned through the lenses of *dramaturgy* and *architecture*. Great architects master the mysterious sense of spatial embodiment and know how perceptual phenomena communicate and connect us to our existence as human beings, like melody and poetry, using silence to play its drums. One example is the architect Steven Holl, who proclaims that ‘space is surrounding us like music as the body is moving through phenomena of space, light, material and detail that convey the art, whether or not the organizing idea is fully grasped’ [20]. Architects challenge science and art by moving from abstract notions to concrete practices of building, sites, and circumstances, through interchanging scalable expressions that stimulate both inner and outer perception of the human body. The surprising ability of material to encompass more than form shows the power of phenomenology within spatial attributes. Dramaturgs are experts in the study of plays, musicals, or operas and can engage participants through vital knowledge and interpretations about themes, language, period, history and music.

4 THE CULTURAL JOURNEY IN XR-LAB COLLABORATIONS

XR-experiences are pieces of computer software formed during a collaborative exercise of the imaginations of the creator(s) of a program and the people who will use it. Therefore, the collaborative exercise is important to understand. This section provides an insight in the XR-lab’s collaborations throughout the years by explaining (4.1) its setup, (4.2) the most important ways of thinking and (4.3) the results of a quick and dirty experiment in 2021.

4.1 The XR-lab setup

The XR-lab has explored all sorts of interdisciplinary formations over the last six years, as each semester offered a different student- and teacher population and the mélange of participating disciplines varied continuously. To adapt to these dynamics, a networked learning environment started from a fragmental and open perspective that fluently could adapt to custom needs in the design process. Each semester released new combinations of talent that shaped into *mosaic pieces of collaborative teamwork*. The emphasis in collaborative practice has been to understand and learn from issues when knowledge transfer has gone bad. This balanced act of *interpersonal dialogue* and high emphasis on attentiveness in human relationships has resulted in successful collaborations that form a consistent part of the design practice.

4.2 Ways of thinking

The most important ways of thinking that have been identified in the XR-lab are *artistic thinking*, *design thinking* and *system thinking*.

4.2.1 Artistic Thinking

According to Mednick (1962), artistic (creative) thinking originates from ‘the forming of associative elements into new combinations that emerge out of intuitive practices and the temporarily liberation of the human mind from existing structures and pathways’ [13]. Artistic thinking provides the ability to synthesize knowledge from a variety of cultural perspectives, dramatic forms, theatrical conventions, and personal beliefs, using technologies to create mosaics and compositions ‘led on by the stylistic and sensual qualities of its parts and their formally arranged relationships’ [3].

4.2.2 Design Thinking

Design Thinking is defined as an ‘intangible, unquantifiable way of thinking, using a non-linear, iterative process and redefines problems

and creates innovative solutions to prototype and test' [2]. It involves five phases — empathize, define, ideate, prototype and test, and is most useful when tackling problems that are ill-defined or unknown. Design Thinking originates from skills possessed by designers, yet over the years the style has evolved into a clearly quantified set of design frameworks, methods, and tools [9].

4.2.3 System Thinking

System Thinking can be seen as a process to see patterns and changing dynamics as well as a framework for seeing interrelationships rather than things. By viewing a problem, system or organization via system thinking, it is possible to achieve vastly different results, ideas, or techniques than if one analyzed individual pieces of data in isolation. Systems thinking can provide insight into the complexity of patterns, connections, leverage points, feedback loops and the human qualities of judgment, foresight, and kindness [12].

Participants	Creative Thinking tools	Design Thinking tools	System Thinking tools
Game developer A	wordcloud	researching human emotion and music styles	programming
Game developer B	moodboard	user journey, lighting changes in Unity	script layouts, making multiple API's work together, lighting and environment cohesion
Web designer C	character design	storyboard, floor map	rewriting the script of the story
Web designer D	moodboards	user journey, storyboard, brand mapping, floor map, research audio clips, brainstorm	learning to work with audio in Unity
Fashion designer E	visual research, analysing research to find connections, form a concept, moodboard, storyboard	virtual identity, movement analysis, UX research, looking for relations, visual translation, connections	finding overall connections, combined with visuals, analyse visuals as a tool to create a system within the concept
Fashion branding designer F	moodboards	storyboards, brainstorm, floormap, designing emotions	not yet

Table 1: Participating students mapping design tools in their own words.

4.3 Ways of thinking employed in the XR-lab

4.3.1 A quick and dirty experiment

The open space of the XR-lab has not always been easy for students. Students often have to deep dive into a steep learning curve for understanding how to design for XR-realities. The hands-on, dynamic, and fluid nature of XR-prototyping could stand in the way of the service-oriented mindset and reflective practice of design thinking. To understand how creators in the XR-lab defined their personal

design process, we asked a small group of six students to map the design tools in the three categories of thinking. They were asked to reflect on their design practice and explain their individual process. Table 1 shows the overall results of the participants in this experiment. This experiment showed that most students start from the way of thinking that they have been familiar with, so developer students usually emphasize on system thinking, web-designers on design thinking and fashion students on artistic thinking. However, students do move towards other ways of thinking whenever they enter new disciplines. For instance, all students were modelling 3D-objects in programs that they had not used before (e.g. Blender, Maya, Substance Painter, CLO3D), and worked in community. This led to a mashup of tools and ways of thinking. When faced with abstract levels of design, we saw that students operated in cross-disciplinary cooperation, holding hands when entering unknown territory. For instance, web-design student (C) cooperated with (fashion) branding student (F) for rewriting the script and storyboard of the story. Student (E) showed that she was capable to explore form and interaction through all ways of thinking. These all-round students usually show that they are highly skilled in exploring XR from a 3-dimensional perspective and integrate the imaginative, visual, and relational aspects in the design practice. In the XR-lab, system thinking was mostly done by software engineers and game developers, but also students from communication and marketing. Students of fashion design proved to be the artistic thinkers, but some fashion designers also make use of system thinking to understand patterns and formations, for instance in virtual knitting and 3D-weaving.

5 DESIGN METHODS AND TOOLS FOR EXTENDED REALITY

Section 4 has shown that in XR-collaborations artistic, design and system thinking flow and merge with each other, igniting new combinations of thought that did not exist before. This leads to new pathways in design and opportunities to explore the interdependent relationships of XR-disciplines further in-depth. In this section, we list the building blocks that support all stages of the design process of XR. These tables show an overview of design methods and tools that have been explored in the last six years of the XR-lab and can support the understanding and learning of how to design for futural XR-experiences.

5.1 Design methods and tools for Extended Reality

Artistic tools and techniques
<i>Tools for Dramaturgy</i> Narrative Structures, Screenplay, Scriptwriting, Storyboard, Scenario
<i>Tools for Performance!</i> Role-playing, Building Character, Actor Movement, Bodystorming, Choreography, Scores (track drawings to AI dance), Grounding exercises, Breathing exercises
<i>Tools for Sensing</i> <i>Eyes</i> - visual feedback and graphical presentation, Moodboard, Film, Video <i>Ears</i> - auditive feedback and acoustic presentation Soundscapes, Audio cues <i>Skin</i> - haptic feedback and force and tactile presentation, Tactility Board <i>Mouth</i> - Charcuterie Board <i>Nose</i> - Scent Strips and Bottles, Diffusers

Table 2: Artistic tools and techniques for ideation, representation, annotation and assessment.

Design tools and techniques
<i>Tools for Architecture</i> 2D - sketching, bubble diagrams, floor plans, exploded View, moodboard, film and video, soundscapes, tactility board 3D - mockup and maquette, XR-prototypes
<i>Tools for User Experience Design</i> User Research - cultural probes, interviews, observations, focus groups, generative sessions, empathy map, user journey, body mapping, embodied ideation, sketching, brainstorming, bodystorming
<i>Tools for Interaction Design</i> Choreography - content canvas, action spaces, proximity scales Psychology - mental models, affordances, use cues, microinteractions Somatosensory or in-bodied - body mapping, body storming

Table 3: Design tools and techniques for ideation, representation, annotation and assessment.

Interaction techniques
<i>Tool for Interaction Techniques</i> Navigation and Locomotion - world-referenced, object-referenced, head-referenced, body-referenced, device-referenced, teleportation, walk-in-place, redirected walking Wayfinding - environment, landmarks, maps, compasses, sign trails, reference objects System Control - controllers, menus, commands, commands, props, multimodal techniques Selection and Manipulation - selection, positioning, rotation, scaling techniques Privacy and Data - data canvas and privacy model, circle diagram, cluster map, causal loop diagram

Table 4: Interaction Techniques for ideation, representation, annotation and assessment.

Prototyping tools and Evaluation techniques
<i>Prototyping Tools</i> Physical - paper prototyping, mockup, 3D model, brown boxing (cardboard) Digital-Physical - white boxing (game engine), lo-fi prototype, high-fi prototype
<i>Evaluation Techniques</i> Formative Evaluation - user task flow, heuristic analysis, hierarchical task analysis, cognitive walkthrough, usability testing Summative Evaluation - task-based performance, time-based performance, and A/B Testing, auditive heatmaps, eye-tracking, biometrics

Table 5: Prototyping Tools and Evaluation Techniques for ideation, representation, annotation and assessment.

6 CONCLUSION

This paper has given an overview of many pieces of the puzzle to design for virtual, augmented, and mixed reality, from abstract notions to tangible tools for design. We have shown that the concept of ‘liminality’ in initiation rites can hold many of the human-technology disturbances that will occur in XR, especially now human computer interaction is entering a new evolutionary phase towards human-computer integration. Understanding and learning more about the stages of ‘liminality’ in futural XR-enhancements can be supported by digital-physical explorations in performance art, dance, architecture, and dramaturgy. XR-collaborations show dynamic processes in artistic, design and system thinking that flow and merge with each other, igniting new combinations of thought that did not exist before. This leads to new pathways in design and opportunities to explore the interdependent relationships of XR-disciplines further. Learning environments that start from a fragmental and open perspective support the dynamic adaptation and morphing of thought into mosaic pieces of collaborative teamwork, interpersonal dialogue, and attentiveness to human relationships that ignite the process of creation. The design methods and tools that have been shown are able to organise and support this process in a multitude of forms and shapes, yet it is important to always leave some space for unexpected imagination. This paper hopes to be a mosaic piece by itself, aiming to further explore how to move beyond the separate parts of disciplines, methods, and tools.

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