Insights from Co-Design of Underwater Telepresence and Extended Reality Technologies with Digitally Excluded Older Adults

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Abstract: The Intergenerational Co-design of Novel Technologies In Coastal Communities (ICONIC) project is running co-design workshops with older (50+) and younger people (16-30) to design technologies suitable for older people's wellbeing. We aim to design four novel technologies in extended reality (XR), underwater telepresence (UT), social games and voice interaction. This late breaking report focuses on workshop results for the first two technologies. Ten workshops were held (August 23 - February 24) involving 24 older people and 12 younger people. Our co-design methods were demonstrably feasible although recruiting younger people is difficult. Nevertheless, the thematic and content analysis showed the importance of intergenerational collaboration for the participants, a consistent desire for social interaction aspect in technology design, the existence of a duality between the desire for immersion and connection to physical reality, as well as special attention to cost and accessibility. As an outcome of the co-design process, we are developing prototype systems streaming live video from an underwater 360° camera underwater in the sea and XR presence in a historical building. We discuss some of the crucial considerations of the technology co-design process such as balancing the introduction of existing technology to raise awareness versus idea generation. Insights obtained from ICONIC's co-design workshops are relevant to researchers designing information and communication technologies for older people.

1 INTRODUCTION

Modern technology often neglects older users (Bradwell et al., 2019; Frennert and Östlund, 2014), despite its potential to improve various aspects of healthy ageing, such as building connections to the local environment and community and simply providing entertainment. Designing technologies that promote digital equality becomes imperative, particularly as older individuals face barriers to digital inclusion, and a growing ageing population. Addressing these challenges, the Intergenerational Co-design of Novel Technologies In Coastal Communities (ICONIC) project employs intergenerational co-creation for designing technologies such as extended reality, underwater telepresence, social games, and interactive voice interfaces. This approach recognises that merely relying on empathy within a design thinking paradigm excludes end users from the conversation, and can lead to solutions that overlook their needs and preferences (Bradwell et al., 2019). By involving both older and younger generations in the design process, the ICONIC project aims to create technology that is inclusive, empathetic, and truly responsive to the diverse needs of local communities.

This paper presents a work-in-progress report, comprising a set of preliminary insights from the underwater telepresence and extended reality co-design workshops, that demonstrate the feasibility of the approach and proposes a set of considerations for employing technology co-design.

2 METHODOLOGY

Our approach mirrors Participatory Inquiry methods, integrating research and action through iterative development. We employ Research through Design (Andersen and Wakkary, 2019), extending Participatory Inquiry, ensuring stakeholder involvement from problem-framing to interaction design (Vasconcelos et al., 2023). The overall steps of the co-design

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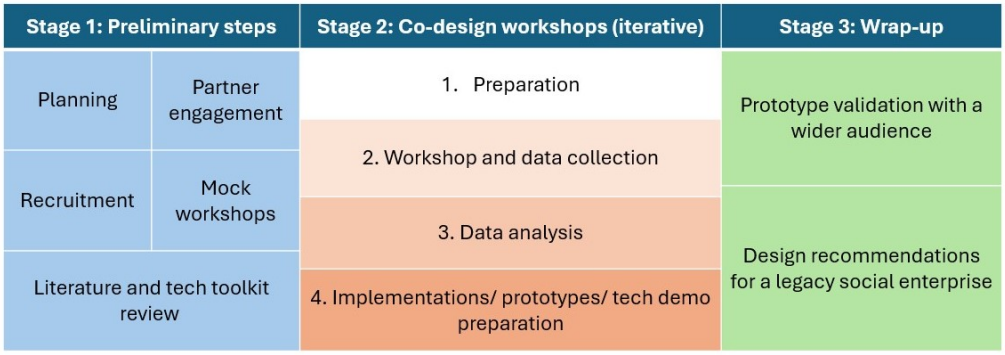

Figure 1: Visual description of the co-design process that includes 3 distinct stages: Preliminary stage focused on preparatory activities - this stage is run before the workshops start, Iterative Co-design workshops focused on hands-on design approaches and the Wrap-up phase - focused on validation and data dissemination leading to the establishment of at least a social enterprise.

process are shown in the Figure 1. The process is divided into three distinct stages. The first stage, *preliminary steps*, aims at establishing a connection with the partners, recruitment of participants, cross-disciplinary planning, literature and technology review and mock workshop to test co-design methodology and logistics. Second stage, *co-design workshops*, is performed as an iterative process exploring a set of problems and challenges solved by the co-design team in an iterative manner. The main steps are: preparation, workshop activity and data collection, data analysis and knowledge generation and, finally, technology/design approach implementation. The last stage of the overall co-design process, *the wrap-up stage*, is used for technology validation and refining the approach and the technology through co-design workshops. At this stage, we intend to release the findings as academic contributions and we create an open-source framework with the potential to be used by social enterprises to establish a new business venture with a social aspect.

2.1 Workshop Planning

The co-design workshops were held monthly, to make sure sufficient time is given for data analysis and technology development, with each technology undergoing 7 to 10 workshops. The long-term engagement of the participants ensured consistency in the design direction throughout. This structure facilitates planning, development, workshop delivery, and knowledge generation. From the development point of view, this design is reminiscent of agile methodology, with iterative product development and evaluation cycles (Cockton et al., 2016).

2.2 Recruitment

We collaborated with 35 local organizations to recruit older (50+) and younger individuals (16-30). Ethical clearance was obtained from University of Plymouth Arts, Humanities, and Business Research Ethics and Integrity Committee (09/05/23; project ID 3941). Recruitment was primarily driven by partner organizations sharing project adverts with potential participants. Participants receive vouchers as reimbursement, with additional vouchers available to cover transport costs. Prior to joining workshops, participants were interviewed to identify their pre-workshop levels of digital engagement, revealing varied levels of digital exclusion, with common barriers being skills, cost, and infrastructure limitations associated with coastal and rural regions (Van Dijk, 2020; Helsper, 2021; Network, 2003).

2.3 Data Collection and Analysis

Data was collected during workshops in form of voice recordings, videos, feedback forms, questionnaires, facilitator notes, as well as hard copy materials from prototyping activities. The data was then analysed using a mixture of thematic coding and content analysis to extract user preferences and priorities, akin to ”user stories” to facilitate the development of the prototypes. The identity of the participants was protected by anonymisation throughout the process.

3 TECHNOLOGY CO-DESIGN OUTCOMES

Despite the common core idea of increasing digital inclusion and well being, the two technologies we are

developing are engaging with different themes: UT aims to create a deeper connection with the natural environment, while XR is aiming to build immersive interactions with local heritage. The design process for each technology has produced specific insights; however, we have also uncovered certain themes that span across both technologies.

3.1 Underwater Telepresence

Informed by the positive impact of blue spaces on wellbeing (Grellier et al., 2017) and the project focus on coastal communities, our aim is to recreate an underwater experience for people while they are onshore, offering them the opportunity to explore otherwise inaccessible marine environments. The general theme of the workshops was to build an optimal interaction with the marine space that could lead to the "feeling of being underwater", while also meeting some of the practical challenges of such a design.

Initial co-design workshops highlighted various barriers to engaging with the underwater world, including financial constraints, time limitations, physical limitations, and discomfort in cold water. While the team was considering to build a remotely operated vehicle for the experience, a scoping review led us to explore alternative technological approaches to underwater telepresence, each with its own considerations regarding accessibility, interactivity, installation complexity, and maintenance requirements.

3.1.1 Co-Design Process

From September 2023 to February 2024, in collaboration with the National Marine Aquarium (Plymouth, UK), we conducted five workshops involving 12 older and 6 younger people - the first set of workshops planned for UT development within ICONIC.

Through focus groups, problem-framing exercises, design thinking workshops, physical prototyping, and demonstrations of related technology (such as, simulated underwater experience using a VR headset "Ocean Rift", a number of 360° underwater videos, demonstration of large language models), a consensus emerged for an immersive, real-time experience of the local underwater environment with interactive access to information about marine life. These preferences informed the development of a conceptual prototype featuring live video streaming from a stationary 360° camera, complemented by a back-end marine life classification engine and a user-friendly interface accessible via a head-mounted display and interactive controllers.

For the second set of the sessions (starting in June, 2024), we are planning to bring the underwater telepresence experience outdoors, to find out how the findings obtained from the aquarium interactions can be adapted to a wider context.

3.1.2 Design Insights

Throughout the workshops, we found that the participants were equally drawn to two opposite modes of interaction: stimulation and relaxation. The stimulating mode was characterised by dynamic and engaging experiences through gamification and interactive features, such as engaging with educational information about marine life. By contrast, the relaxing mode aimed to provide a tranquil and soothing environment, to focus on the wellbeing benefits associated with blue spaces (Grellier et al., 2017).

Learning about marine fauna and flora was a big and consistent focus in all the workshops. We have addressed this need by integrating elements of machine learning and interfacing the prototype with a remote large language model API for generations of explanations about marine life.

The role of live streaming as an element of building a long-term engagement was suggested in the workshops through the interaction with the publicly available live underwater camera stream. The participants highlighted that the content must be different and varied to be engaging long-term, also mentioning the special allure of "observing it, as it happens". This long-term engagement contrasts the short-term interactions usually designed for such applications.

3.2 Extended Reality

Enabling individuals with mobility impairments to access culturally and historically significant sites, our project addresses the limitations of commercially available VR systems while fostering connections with specific places and communities, and supporting user wellbeing (Alliance, 2020; Pennington and Corcoran, 2019; Ateca-Amestoy et al., 2021). Building upon prior efforts in the field of XR system development for digital heritage sites, which focused on comparable sites including Powderham Castle and the Higher Uppacott medieval site in Dartmoor National Park (Reyes et al., 2023), our focus is Cotehele, managed by the National Trust, a group of medieval buildings and historic gardens in Cornwall with strong connections to the local community. Despite local efforts to enhance accessibility, the site presents challenges such as narrow corridors, steep steps, and limited public transport.

3.2.1 Co-Design Process

From August to December 2023, we conducted five workshops involving 12 older and 6 younger people. Utilising the Meta Quest 2 headset, participants experienced immersive VR encounters, engaging in various activities to document, experience, and speculate on historical sites and their potential to promote well-being principles such as social cohesion and intergenerational interactions. These activities encompassed 360° video demonstrations, persona-based experience design sessions, and ergonomic testing of XR hardware for older users, resulting in tailored control and handling functionalities for the Quest 2 headset. Additionally, we collaborated with the Cotehele team to 3D scan and document artefacts that will be implemented at a later date in the project as part of a local narrative. XR workshop activities will resume in June 2024, focusing on integrating locomotion and interaction design elements, as well as incorporating narrative and storytelling strategies into the final XR experience co-design.

Figure 2: Screenshot from an early digital version of Cotehele, Inside the Great Hall. The participants explored the interaction and the environment to get a sense of space and explore various types of locomotion suitable for that space.

3.2.2 Design Insights

An XR experience implies metaphorically transporting the user to a digitally constructed reality, away from where the user currently resides. Typically that requires going beyond the sense of depth provided by a stereoscopic view of a head-mounted display. The more the user's sensory stimulation is triggered with inputs from the digital environment the more immersed they become, leading to a sense of place illusion or presence (Slater, 2018).

This aspect was very clear from the first VR experience the intergenerational group of co-designers took part in. The session focused on exploring the sense of scale and space from a participant's egocentric point of view using 360° videos captured at various locations inside the Cotehele Heritage site (Figure 2). The dominant feedback feature was a lack of interaction and frustration with the inability to move inside the virtual space. Users' senses were triggered solely by the visual stimulus while the rest of the senses were rooted in reality therefore breaking the illusion.

Upon the introduction of interactivity and navigation, the immersion levels increased but two main barriers arose. The lack of familiarity with the VR controllers led some participants to lean towards more intuitive modes of interaction such as hand tracking which comes at the cost of losing haptic feedback. The second stumbling block is more physical in nature, presented by limited thumb dexterity or inability to close the hand around the controller displayed by some of the older participants. This presented a challenge with even simple tasks such as squeezing the side button on the controllers or moving the thumbstick at the top of the controller.

As a result, for the remaining sessions for XR, we are planning to introduce a series of workshops that focus on the co-design and integration of a custom controller (unique mapping of a controller or perhaps a specially built controller) that satisfies the range of mobility presented by the participants and maintain the immersive element of the experience.

3.3 Cross-Track Themes

Through both technology tracks, the intergenerational aspect was evident from the behaviour of the participants in the workshops and in their self-reported experience. Participants highlighted the importance of diverse perspectives for ensuring the inclusivity of the technology design process. The intergenerational dynamics were particularly evident in the hands-on activities such as physical prototyping, where the younger participants took initiative in making the prototype, while the older adults provided guidance during the process.

The participants in both workshop tracks were mindful of the cost considerations and accessibility of the final design. For example, in XR workshops, as the creation of an additional haptic sensor was discussed, participants expressed a worry that it will increase the overall cost of the design.

While in both technologies, the allure of the immersive spaces was evident from the participants' feedback, there is a consistent conflict between the desire to be immersed in the virtual space and the discomfort of feeling disconnected from the real world. This was addressed in UT track by giving a chance

to participants to interact with the 360° immersive portable dome (Figure 3) for comparison with the use of a headset.

Similarly, participants in both tracks consistently expressed a desire for a social interaction aspect in the technology design. To further address this preference, in the second part of the project, a dedicated workshop will focus on the development of a social interaction metaphor for the participants. For the XR track, through a co-design approach, the participants will use technology such as Quest Pro (Meta, 2024), that facilitates social interaction. The head mounted display social features, such as eye tracking and facial expression recognition, will provide the participants with the tools to create a social experience and increase collaboration in the virtual world. In the UT track, we will further engage with participants' initial suggestions by implementing a social interaction aspect through a gamified activity focused on recognizing marine species.

Figure 3: The participants of the UT workshop evaluate the interaction experience with underwater footage via a semi-portable immersive dome by Fulldome.pro.

4 CO-DESIGN PROCESS CONSIDERATIONS

In the overall co-design of technology we have encountered a number of trade-offs that require careful balancing for a successful co-design process.

4.1 Building Technology Awareness

It is important to build awareness of the possibilities of technology among our participants to empower them to generate ideas in a grounded way. In general, with every workshop, the participants gained more knowledge and confidence, which enabled them to focus more deeply on co-creation with subsequent workshops requiring fewer technical explanations and details.

The balance between the educational aspect of the workshops and co-creation was important. For example, participants needed to be comfortable in using VR head mounted displays to be able to indicate their preferred elements of interaction. As many people in our workshops had never engaged with the VR headsets, we set up additional one-on-one VR training sessions.

There is a certain risk, however, of imposing specific technological solutions early on that might limit exploration and creativity. Being mindful of this effect, in UT track, the very first session was solely dedicated to the participants' prior interactions with the marine environment and National Marine Aquarium tour, without any technology engagement.

4.2 Balancing the Practical Limitations

While it is best for the co-design process if participants bring forth imaginative ideas during the ideation stage of the development, practical constraints inevitably surface in the design process. In our case, the main constraint is development time, as only one researcher was developing each of the technologies. We found that participants were receptive to the conversation about the limitations of the project, and the outlined scope of the initial prototype development, while still staying creative and imaginative.

Moreover, in many cases, it is possible to identify the deeper motivation behind suggested features and consider the possibilities of alternative implementations. For instance, during one of the UT workshops participants came up with an idea of social interaction in marine space via avatars. While we are unable to implement this directly, it signals a desire for a social interaction aspect of the design.

4.3 Representation and Recruitment

Representation of our target population of older digitally excluded people is limited as our sample is to some extent self-selected, where participants volunteer to take part in the workshops. While this approach offers insights from the individuals actively engaged and interested in the project, it may not fully capture the perspectives of those less inclined to participate. We are planning to address this limitation by holding additional sessions to evaluate whether the design was truly representative of the preferences of a wider audience.

Despite targeted outreach efforts, we have en-

countered difficulties in engaging certain demographics, particularly younger individuals with limited availability due to work or education commitments. We are addressing this by further contacting more local educational organizations and holding separate sessions for younger individuals so trialing an asynchronous intergenerational co-design.

5 CONCLUSION

Co-design holds significant promise for technology development. By addressing key limitations and trade-offs in the co-design process, such as ensuring participants understand the potential and practical constraints of technological solutions, we can effectively engage the general public, particularly older adults, in creating digital technologies.

Within ICONIC, we plan to conduct four additional co-design 'sprints', each spanning six months and focusing on one of the four technologies (Underwater Telepresence, Extended Reality, Voice AI Interface, and Social Games). These sprints will be complemented by one-off sessions for evaluation and additional feedback, as well as dedicated workshops for younger participants.

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