ENHANCING THE XR+ METHOD: A USE CASE IN RESCUE HELICOPTER CABIN DESIGN

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ABSTRACT

The cabin design for future rescue helicopters presents unique challenges due to the integration of the diverse needs of its users such as paramedics, patients and pilots. Within the CHASER project, the German Aerospace Center (DLR) aims to create a digital, user-centred cabin concept for future medical deployment vehicles. With the increasing demand for user-centric cabin solutions in the aviation industry, the need for innovative design methods which bring the requirements of the end-users into the conceptual design have become increasingly important. The XR+ method combines traditional co-design techniques with Extended Reality (XR) as a way of engaging and involving end-users early in the design process, creating a more flexible and iterative approach to cabin design. By providing both an interactive hands-on and immersive environment, XR+ enables users to engage in the design process in real time, facilitating them to put their needs to the forefront of the design. This paper represents an initial attempt to demonstrate how the XR+ method can contribute to the design of the cabin of a primary rescue helicopter. This study uses the CHASER project as a use case to apply and further progress the XR+ method. Two experienced Helicopter Emergency Medical Services (HEMS) professionals participated in a three-phase workshop. This included a ‘sensitization’ questionnaire, physical model creation using a three-dimensional toolkit, and immersive XR evaluation. Findings indicate that XR enhances spatial understanding and creative ideation, while the three-dimensional toolkit provided more ease of use. However, a learning curve and challenges in collaboration in some areas were observed while using XR. By directly involving users in the design process, the study serves to lay the first foundations for reducing the development effort required for complex air rescue cabin concepts, ultimately contributing to more efficient and accessible design solutions. Furthermore it has the potential to address other design challenges such as commercial aviation cabins. It provides a structured solution for involving users, reducing costs through low-level mockups and facilitating collaborative design.

Keywords
co-design; co-creation; cabin; helicopters; rotorcraft; rescue; extended reality; virtual reality; participatory design; design research; aviation

1. INTRODUCTION

Designing cabins for future air transportation concepts is complex. Systems and subsystems have to be linked correctly ensuring technical performance and safety. However, one of the most challenging aspects is addressing the evolving needs of users. As user requirements change, cabin designs must remain flexible and user needs have to be adapted as early as possible. This becomes even more critical in specialised areas such as rescue helicopters where the cabin serves as a crucial interface for mission success between the technology and its users: paramedics, pilots and patients. This study explores Extended Reality (XR) as a means to involve the user into the design process. According to Tremosa (2024) “Extended Reality (XR) refers to a range of technologies that modify reality by integrating digital components into the physical world, encompassing tools such as Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR)” [1]. Furthermore, the “X” in XR represents any given variable. The German Aerospace Center (DLR) is investigating (virtual) design methods to flexibly develop and evaluate concepts with users in early stages of the design process. This fits into the broader vision of DLR integrating digitization through virtual OEM and Digital Thread practises with the goal of enhancing aviation’s efficiency, flexibility and sustainability. In turn this vision aims to bring together multiple specialities and disciplines within DLR, creating a collaborative environment that bridges the gap between individual fields, aiming for a more integrated design process. This collaborative framework ensures that each aspect of the cabin design—whether technical, operational, or user-oriented—is created in synergy with one another.

However a collaborative approach when designing for specific users can only flourish when involving those users directly in the design process. This is also known as co-design, a term that will be elaborated on in the next chapter. This user involvement is highlighted by Sanders & Stappers (2008) who emphasise that the real experts in designing future experiences are the users we aim to serve through the design process [2], advocating for a shift towards designing with users, rather than for them. An approach to put the user first in cabin design can be found in the DLR project ‘CHASER’ (Conceptual Handling Assessment Simulation and Engineering of Rotorcraft). This project focuses on the design of a primary rescue helicopter. This configuration is part of the DLR Guiding Concept 4, 'LK4 Rescue Helicopter' (Leitkonzept 4). LK4 is a strategic research program uniting several DLR institutes to achieve a common goal: advancing rescue helicopter design. In an early phase of the CHASER project, an initial conceptual sizing study was conducted [3] to meet enhanced flight performance requirements. At the same time, researchers developed a new fuselage concept with a more drag-optimised shape, designed to allow patient loading through side doors. This fuselage is currently under investigation as part of the DLR Urban Rescue project, and a recent wind tunnel campaign was conducted to assess its aerodynamic performance [4]. Figure 1 shows a photograph of the wind tunnel model in the test section of the Deutsch-Niederländischer Windkanal – Niedergeschwindigkeits-Windkanal Braunschweig (DNW-NWB).

FIG 1. Wind tunnel model of the LK4S1

Concluding the initial sizing of the overall configuration, in this study emphasis is laid on prioritising the needs of key stakeholders such as paramedics, patients, and pilots for enhancing operational efficiency and user experience [5]. Aircraft frequently used as primary rescue helicopters are usually not designed exclusively for this task alone. Other tasks can be carried out by the same models of aircraft with modified cabins. For instance: secondary medical transport, Search and Rescue (SAR), or in other branches, law enforcement, offshore operations and private transport. The cabin is a key area that connects the user to the aircraft. This makes it a vital interface for meeting the varied needs of the people on board. However, aligning user requirements in this context can be challenging and lengthy due to the diverse needs of each group.

Therefore, this research shows approaches to align the needs of end users in a co-design environment. Doing so has great potential for synthesising a design that fits the needs of users while cutting costs and development times. This paper will build upon the foundational XR+

method which emphasises the importance of early stakeholder involvement outlined in prior research [6]. The XR+ method advocates blending a traditional co-design technique innovatively with Extended Reality (XR). This research will explore its application with rescue helicopter workers in the CHASER project, laying the first foundations for new user-centred cabin solutions for a primary rescue helicopter.

2. CO-DESIGN WITH THE END-USER

Co-design is a user-centred design method where designers and (end) users are actively involved in the design process. The term 'user-centred design' can be defined as a design approach that puts the user centre stage during the entire design process. "Instead of focusing on technological possibilities and quality measurements in terms of components, it takes solutions that fit the user as a starting point and measures product quality from a user point of view" (Vredenburg et al. 2002) [7]. While user-centred design focuses on understanding and designing *for* the user, co-design involves designing *with* the user. This involvement is aimed at design exploration, envisioning and solution development [8]. It is about empowering those who are affected by the final design outcome but not traditionally part of the design process. It is a process where designers work together with non-designers [9]. It gives voice and tools to the people and/or end-users to participate in the design process. The emphasis is on user engagement and collaboration with the goal to provide a platform to meaningfully contribute [8]. Given the appropriate tools, users can become part of the design team as 'experts of their experience' as stated by Sleeswijk Visser et al. 2005 [10]. In turn aiding the designers and others in the workshop to better understand the struggles and needs of participants, encouraging them to think out of the box and beyond their own assumptions.
In the case of this study the participants of our workshop are the rescue helicopter workers.

Co-design can be particularly helpful in aircraft cabins where the needs of different user groups must be balanced. In figure 2 we see flight attendants engaged in a co-design workshop. They were tasked to design their ideal galley in a new type of aircraft concept, the Flying-V [6]. This TU Delft concept is as stated on the TU Delft website as "a design for a highly energy-efficient long-distance aeroplane. The aircraft's design integrates the passenger cabin, the cargo hold and the fuel tanks in the wings, creating a spectacular v-shape." [11]
Since the flight attendants will be working in this galley, and the Flying-V represents a radical new aircraft design, their input allows stakeholders to address practical needs early in the design process. In turn, more informed and user centric decisions can be made, saving time and costs in the future.

FIG 2. A Co-design workshop with KLM flight attendants.

There are many ways in which co-design can take shape and according to the task at hand a method or technique can be used. In this study we will be using a generative three-dimensional toolkit [12]. The addition of Extended Reality to such a toolkit is the basis for the XR+ method. Research shows that XR technologies can significantly enhance collaborative design experiences by providing interactive and immersive environments for users. [13]. The combination of XR and generative toolkits lies at the basis of the XR+ method.

3. METHODOLOGY

XR+

The workshop in this study builds upon the XR+ method, initially developed at the German Aerospace Center (DLR) and TU Delft in collaboration with flight attendants from KLM (Royal Dutch Airlines) [6]. This method integrates XR technologies with (traditional) co-creation methods to enhance stakeholder involvement early in the design phase. The original XR+ method was inspired by the collaborative creation method of hospital rooms as described by Sleeswijk Visser (2013) [14]. Following the success of the method in designing part of an aircraft cabin for the Flying-V with the input of KLM flight attendants, this study applies the approach to the design of a medical rescue helicopter cabin with its crew. Since the method is now focussed on a different use case, adaptation in some areas is needed to cater to the needs of the participants. Hence, additional tools and materials were produced for the helicopter rescue workers. Due to the logistical challenges of gathering such specialised participants, this pilot study represents an initial exploration of the method's applicability to the field of emergency medical services. The focus in this iteration has shifted from KLM cabin crew to paramedics and emergency physicians , with the goal of assessing whether the XR+ method could facilitate effective cabin design solutions for these users. This study evaluates the method's reception and effectiveness in a new context, aiming to validate and refine the XR+ approach for a broader range of applications in the future.

Workshop participants

The study involved two experienced professionals from the field of emergency medical services (EMS), both with extensive experience in helicopter emergency medical services (HEMS). Participant one identified as TC-HHO/HEMS (technical crew member and medical professional within Helicopter Hoist Operations (HHO) and Helicopter Emergency Medical Services (HEMS)) While participant two is an emergency physician and regional medical director for the German Air Rescue service.

Workshop Process and Tools

In figure 3 a general layout of the method can be observed.

FIG 3. The general layout of the XR+ workshop.

The XR+ method comprises three phases which each play a role in the development of the (co-)created concepts created by the participants. These being the pre-workshop, workshop and post-workshop phases. The workshop itself consists of two major stages after the introduction. The first stage will use generative tools to support participants in their design efforts. The second stage will introduce XR as a method to continue the designing in an immersive manner. This way of working has so far only been tested out with KLM flight attendants for a specific use case. To the best of the authors' knowledge, the addition of a 'sensitization' pre-workshop phase, combined with a hands-on physically immersive workshop utilising XR, outside the context of passenger aircraft, has not been explored in prior studies.

Pre-Workshop Phase (Sensitization)

The Pre-Workshop involved a 'sensitization' questionnaire that aimed to gain initial insights into the experience and concerns of the participants. This approach loosely follows the 'Path of Expression' framework (Figure 4) as proposed by Sanders & Stappers (2012) [15].

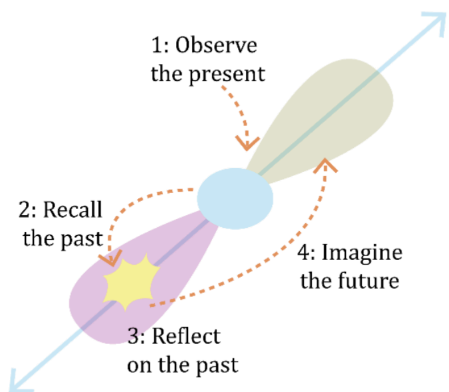

FIG 4. The Path of Expression

In this framework, the process begins by observing the present, then recalling past experiences. After reflecting on these past experiences, the focus shifts toward imagining possible futures. These futures were then drafted in the workshop.

The pre-workshop phase involved engaging the two participants through a ‘sensitization’ questionnaire. This questionnaire is designed for the participants to reflect on their everyday experiences within their current job as helicopter rescue workers. The questionnaire gathers insights into their professional experiences and thoughts on current and future cabin layouts. This approach is based on the “Sensitizing” method as described by Sleeswijk Visser et al. (2005) [16] where ‘sensitizing’ is a way of preparing the participants for the session by giving them insights into their experiences through self-reflection assignments. This was done using a survey created in TypeForm (Figure 5) an online platform supporting a variety of different question types such as open-ended questions, multiple choice and the option to add media such as images to the questions.

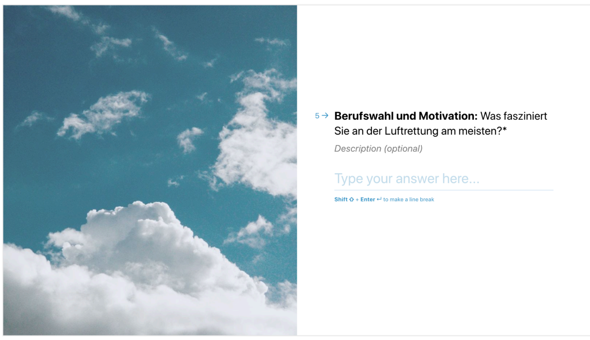

FIG 5. A screenshot of one of the questions in the ‘sensitization’ questionnaire.

The process of ‘sensitizing’ takes time [16]. The questionnaire was therefore sent out a week before the workshop took place and was meant to align the participants’ perspectives preparing them for active involvement in the design process. The answers provided in the questionnaire were used by the facilitators to gain insight into the minds of the participants prior to the workshop. For the participants themselves, the questionnaire was meant to prime their minds for the upcoming workshop.

Workshop Materials

The pre-workshop phase also involved the setting up of materials such as the timetable and keynote presentation. More importantly it included the building of the physical and virtual assets that are used during the workshop by the participants, in this case our end users.
As mentioned by Sanders and Stappers (2008), “when we acknowledge that different levels of creativity exist, it becomes evident that we need to learn how to offer relevant experiences to facilitate people’s expressions of creativity at all levels.” [17] Or in other words, people need the right tools to express themselves creatively. “The use of generative design tools lets one look forward into the possible futures” Sanders (2008) [17]. Inspired by the generative toolkit from Sanders (2006) used for mocking up hospital rooms [18] and the previous iterations of the XR+ method [6] a 3D model of a possible outer hull of the rescue helicopter was prepared in Rhinoceros 3D. The model was 3D printed on a Prusa MKS4 printer on a 1:20 scale. The fuselage concept is similar to the wind tunnel model shown in Figure 1. The print consisted of multiple parts which were later glued together to form half of the body of the helicopter fuselage. This was one of the models to be used as a generative design tool. Prior to the workshop it was imported into the XR application Gravity Sketch. For size reference, mannequins in different poses representing average German male and female height [19] were made in Gravity Sketch and prepared in the 3D software Blender for 3D printing on a 1:20 scale on a Prusa MKS4 printer.

FIG 6. The three dimensional toolkit used for physical prototyping.

The three-dimensional toolkit consisted mainly of 3D printed pieces that were used in the initial XR+

Flying-V project [6] and were recycled for this workshop. These included multicoloured plastic shapes in multiple different sizes. The addition of transparent 3D printed parts was added to the inventory for this study. These were modelled in Blender

Workshop-Phase

As the XR+ method uses both traditional and XR based co-design, the workshop was structured in two primary stages to integrate both. In this case the use of a three-dimensional toolkit, and a collaborative XR space.
After formal introductions and discussion of the agenda for the day, the workshop began with an 'energizer'- a light hearted ice breaker activity to make the participants feel more at ease and help maintain a positive and lively atmosphere, encouraging creativity and participation during the workshop [20]. After this, participants were asked to write down what they liked and disliked about current helicopter cabins and if they had any thoughts about what a future cabin must include or look like. These answers were then used as a reminder to fall back on for the next stage: the physical modelling.

The participants were each given the three dimensional toolkit for generative prototyping [10] a method described by Sanders and Stappers as using tools that enable participants to visualise and explore ideas by physically constructing models. They were given ten to 15 minutes to design their ideal cabin as can be seen in figure 7.

FIG 7. A participant using the three-dimensional toolkit during the co-design workshop for mocking up an idea.

Using the notes they wrote down earlier for inspiration, participants had to physically build their designs individually with the toolkit. After completion they explained their design and ideas to the facilitators and other participant. From here, the exercise continued with the participants now joining forces and working on one model together. The previously designed models were used as guide and inspiration during the creation of this model.

The physical modelling was then followed by an explanation of the newly created concept and a short break. During the break the facilitators transferred the results of the physical modelling exercise to Extended Reality (XR). This was done by hand by the facilitators by observing what the participants had created. The software Gravity Sketch was used to translate these designs from a physical to a digital environment. The digital designs were brought into a virtual collaboration room where multiple users could virtually interact with the items. For this the XR systems Meta Quest 2 and Meta Quest 3 headsets running Gravity Sketch were used. Both headsets could access the virtual collaboration room simultaneously while a third member could access through a laptop. In this setting participants could interact with the cabin design on a 1:1 scale. A facilitator was present in the XR environment to control and manipulate objects in the virtual world. Because of the limitation of two XR headsets or head mounted displays (HMDs) only one participant at a time could enter the XR world. Participant one entered the XR world and explored and manipulated it with help of the facilitator. After this, Participant two did the same. A monitor in the room allowed the participant who was not in XR to follow along what was happening in the XR world through a laptop to monitor connection.

FIG 8. A participant guided by a facilitator in XR

Post Workshop-Phase (Evaluation)

After the workshop the participants were asked to fill in a questionnaire about their experiences. This questionnaire was mainly tailored towards the evaluations of the XR+ method. The questions aim to understand how these tools influenced spatial understanding, creativity and collaboration during the workshop. It is rather an evaluation of the method used in the workshop than the design outcomes that resulted from the workshop.

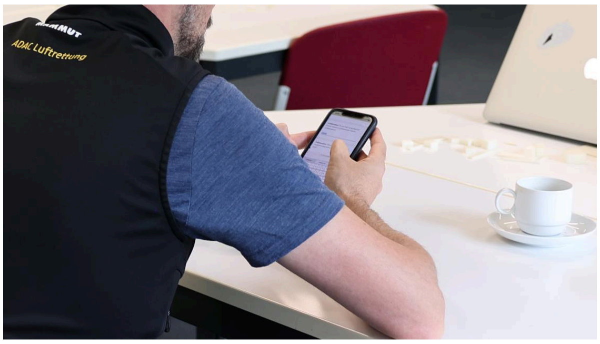

FIG 9. A participant filling out the post-workshop questionnaire.

Data Collection During the Workshop

The focus was on collecting qualitative data given the sample size (n=2). This was done through open-ended questions, direct feedback and discussions with the participants. Some quantitative data were gathered using Likert-scale ratings. Additionally the workshop was recorded on video and the audio was analysed by transcribing the speech in the video using an AI transcribing app. However this service did not provide accurate enough results and the video had to be accessed multiple times for a reliable source of information. Results of the three-dimensional toolkit were photographed in the individual modelling stage and in the collaborative effort. The XR model created during the workshop was saved in a collaborative virtual XR room for easy access at later stages by the facilitators. It can also be exported to other software packages for further iteration.

4. RESULTS OF THE WORKSHOP

The results of applying the XR+ method to the whole session are multifaceted. Note that most scores in the results are rated directly by the participants themselves. For ease of analysis they have been divided into different categories which are listed here:

1. **Spatial Understanding and Visualization**: Examining how the three-dimensional toolkit and XR enhanced participants' understanding of spatial dimensions and cabin layout.
2. **Creative Stimulation and Problem Solving**: Evaluating how the XR+ method stimulated idea generation and facilitated this in different parts of the workshop.
3. **Engagement and Collaboration**: Analysing how engaged participants felt and how they rated their collaboration.
4. **Efficiency and Learning Curve**: Investigating the ease with which participants became familiar with the three-dimensional toolkit and XR.
5. **Real-World Application and Practical Insights**: Evaluating realism the tools provided.

4.1 Pre-Workshop Results

The questions in the ‘sensitizing’ survey were drafted in a way to reflect on current and past practices in air rescue. The questions prompted answers that included motivation and interest in air rescue, operational concerns, challenges in previous missions and design priorities. Both participants expressed optimism regarding contributing to the cabin design process. A focus was placed on practical improvements that could enhance mission success of the workers. The survey responses highlighted the importance of a helicopter cabin that enhances flexibility during rescue missions.

4.2 Workshop Results

The workshop provided insights into the needs of HEMS workers and areas they were focused on. These area's included patient positioning, flexibility, accessibility and ergonomic placement of equipment. The use of the XR+ method shaped the participants' design process and creative output.

4.2.1 Spatial Understanding and Visualisation

Both participants found XR very effective in enhancing their spatial understanding, each giving it a score of 8/10 likely appreciating its immersive nature.

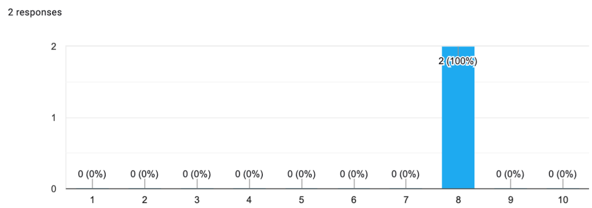

FIG 10. Enhancement of spatial understanding in XR

With a rating of 7/10 and 9/10 the three-dimensional toolkit also received high scores whilst also showing a slight variation between participants.

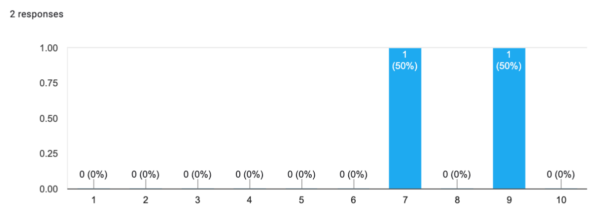

FIG 11. Enhancement of spatial understanding with the three-dimensional toolkit

This could suggest that while the three-dimensional toolkit was helpful, XR gave a more consistent experience for grasping the spatial aspects of the cabin design compared to the three-dimensional toolkit. XR also enabled the rescue workers to experiment with different layouts and objects such as 360-degree rotating seats and modular seating arrangements.

These results suggest XR has the potential for improving spatial understanding, particularly in confined spaces like helicopter cabins. The three-dimensional toolkit could indicate a more universal ease of use.

4.2.2 Creative Stimulation and Problem-Solving

XR's Stimulation of Creative Thought

The creative freedom and output of the participants was guided and influenced by the tools used during the workshop. Different ideas emerged according to the tools used. Participants were asked to rate to what extent XR stimulated their creative thought and if they felt more creative using the three dimensional toolkit or the XR application. They indicated that they felt more creative in XR and rated the stimulation of creativity by XR as 8/10 and 10/10 indicating how the immersive experience inspired their thinking.

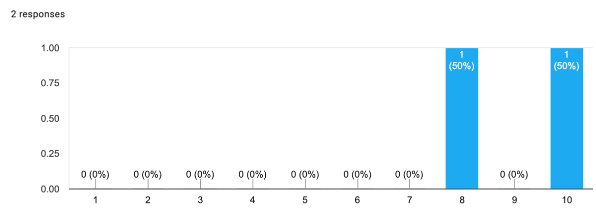

FIG 12. Stimulation of creative thought in XR

While XR was rated highly for stimulating creativity, the participants did not mention the three dimensional toolkit in their answers with regards to creativity.
XR's ability to stimulate creative thought in early phases of the design process highlights its value in exploring ideas beyond physical constraints.

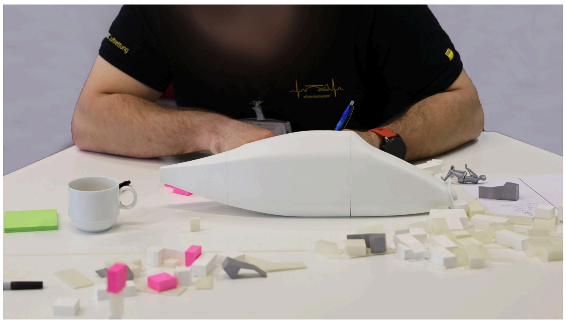

FIG 13. Using the three-dimensional toolkit

Novel ideas generated during the session

The workshop yielded several (self-reported) novel ideas inspired by using the three-dimensional toolkit, XR or both. These will be shown in chapter 4.2.6 and include a turntable-like mechanism for transporting the patients into the rescue helicopter. This was devised in the co-creative phase using the three dimensional toolkit. Initially, this system could only transport two patients, but this idea was expanded to four patients in XR. Furthermore, a concept of small, movable patient monitors was added to this configuration along with overhead storage as observed by a facilitator

4.2.3 Engagement and Collaboration

Participant engagement levels during the workshop

Throughout the workshop the level of engagement was rated with a 7/10 and 9/10 indicating that both participants felt quite engaged throughout the session with one participant rating it slightly higher than the other.

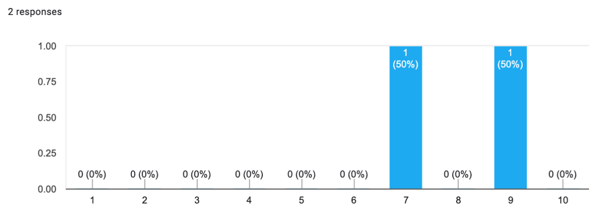

FIG 14. The score participants gave concerning how engaged they felt during the whole session.

One participant described that he felt engaged in both the XR-session and the three-dimensional toolkit session, however XR added to this involvement or 'absorption' making him feel more engaged.

Collaboration between participants

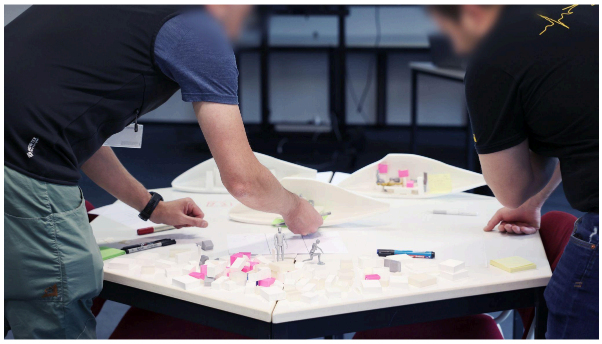

FIG 15. Participants working together with the three-dimensional toolkit

Both participants rated team collaboration positively, with scores of 7/10 and 8/10, suggesting that the team worked well together during the co-design process.

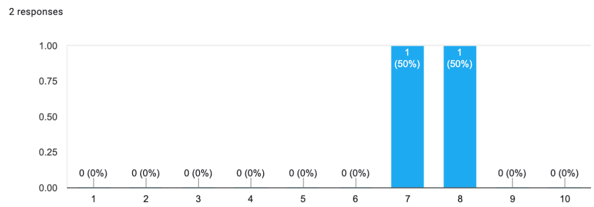

FIG 16. Team collaboration as rated by the participants.

Participants reported that the use of the three-dimensional toolkit helped their collaboration. However, due to a logistical constraint it was not possible to have two participants in XR at the same time. While this arrangement provided valuable insights into individual spatial understanding and design exploration, it restricted the ability to fully assess the collaborative potential of XR between participants in this context.

4.2.4 Efficiency and Learning Curve

Learning curve of the tools used

The learning curve for XR was a divisive issue between participants. One participant rated the ability to learn to control the XR environment as very challenging with a 2/10 (lower is harder to learn) while the other participant adapted quickly with a rating of 9/10. This also corresponds with the time it took for participants to feel comfortable in XR, which ranged from 2-5 mins for one participant and 5-10 minutes for the other.

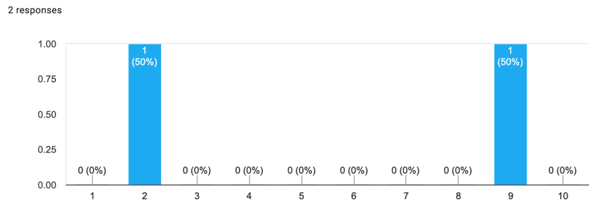

FIG 17. The learning curve in XR

In contrast, both participants rated the ease of using and learning the three-dimensional toolkit at 7/10.

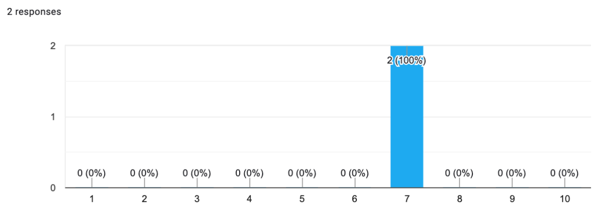

FIG 18. The learning curve for the three-dimensional toolkit.

Efficiency of the tools used

The efficiency of XR was also rated differently between participants with one rating it 4/10 and the other 8/10.

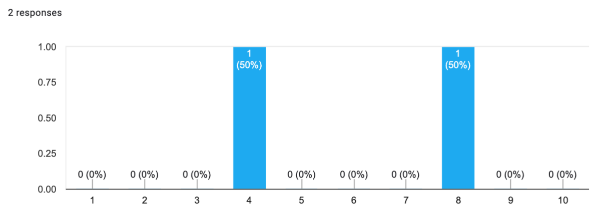

FIG 19. The efficiency of XR aiding in ideation and prototyping.

The three-dimensional toolkit however was rated more consistently at 6/10 and 7/10. One participant felt that XR allowed them to complete their designs faster, while the other did not.

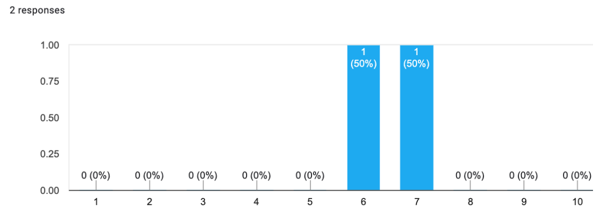

FIG 20. The efficiency of the three-dimensional toolkit aiding in ideation and prototyping

4.2.5 Real-World Application and Practical Insights

One participant noted that *"the XR environment helped foresee practical issues that were not visible with physical blocks."* This highlights XR's strength in previewing real-world challenges, particularly when designing modular, adjustable seating for different patient configurations.

Realism and relatability to a real cabin

The accuracy of the XR cabin representing a real cabin was rated moderately with scores of 4/10 and 5/10. Participants had differing abilities to relate virtual designs to real-world scenarios, with one being able to do so slightly more than the other.

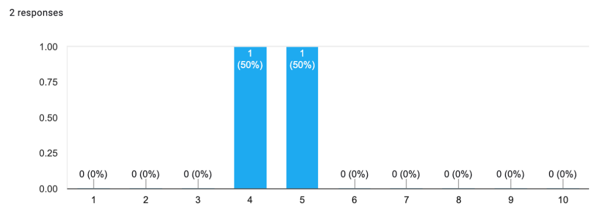

FIG 21. The rating of how realistic participants found the XR world to be.

Transferability to XR

One participant found the shift from the three-dimensional toolkit to XR very helpful for gaining new insights, particularly in experiencing and clarifying the dimensions during the design process.

4.2.6 Final Helicopter Cabin Design Outcomes

Several design solutions emerged from the collaborative workshop. These emphasised flexible seating arrangement, modular patient monitors and clear access to equipment. Figure 22 shows the proposed layout of a turntable mechanism for easily loading and unloading patients into the aircraft from the side.

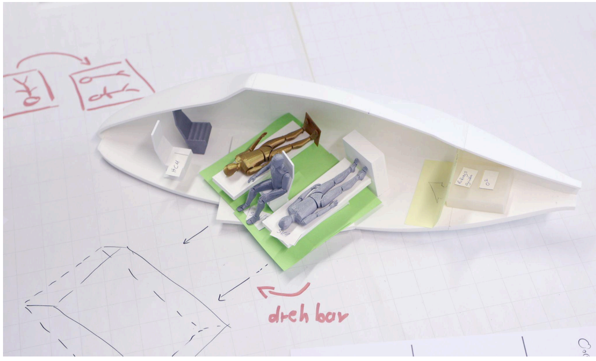

FIG 22. Result of the co-design session using the three-dimensional toolkit.

The current ADAC rescue helicopters H135 and H145 load patients from the rear and there is just enough room for a stretcher with one patient on it. In this new proposed design patients are loaded onto a turntable mechanism which is big enough to fit two patients next to each other. The middle of the turntable provides a seating area for a HEMS worker to provide care to the patients. This chair can flexibly be moved back and forth to the liking of the HEMS worker. Equipment is kept towards the rear for easy access.

Fig. 22 showcases the ideas that were drafted in XR after prototyping with the three-dimensional toolkit. Placement of patients on top of each other was an idea that arose during the XR session. Making room for four patients in the cabin, two more than envisioned first. Here a distinction was made between where to store the most injured and least injured patients, ranging from the codes SK1 to SK3 respectively (Sichtungskategorie). It was found in XR that the most injured patients or SK1 would be best placed on the lower platform nearest to the HEMS worker. Less critical SK2 and SK3 patients could be moved up top. The need for modular patient monitors also became apparent in XR. These would have to be attached to the stretchers that can be switched or moved based on the patient's condition and the type of emergency. A split screen would indicate the condition of the two patients stacked above one another. The monitors would provide information to a HEMS worker sitting in flight direction and a HEMS worker facing opposite direction. The middle aisle has a 360-degree rotating seat, which allows paramedics to easily reposition during in-flight interventions.

This approach made room for up to four patients and was intended as an exploratory concept rather than a strict design goal. The primary objective within the “LK4 Rescue Helicopter” remains to develop a cabin for two patients and two HEMS workers and their equipment. The open exploration with XR allowed participants to experiment with innovative configurations, even if they deviated from the initial design requirements.

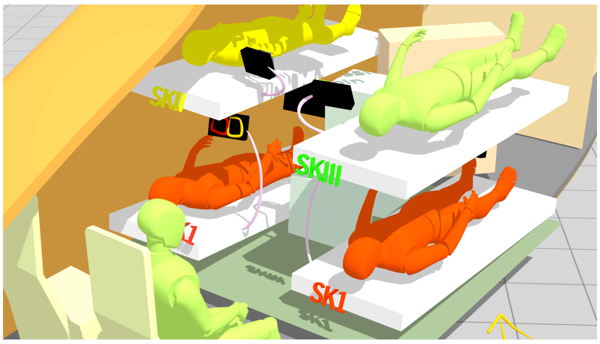

FIG 23. Exploratory result of designing in XR

5. DISCUSSION

Both participants found that XR significantly enhanced their spatial understanding compared to the three-dimensional toolkit. Viewing designs at a 1:1 scale was particularly valuable for assessing how different setups would work in the constrained space of a helicopter cabin. Research supports this, indicating that technological immersion—such as stereoscopy and tracking—often impacts spatial understanding more than visual detail [21] and that the more 1:1 scale, 3D and real it gets, the better it is [12]. While the realism of the XR environment received moderate ratings (4/10 and 5/10), this may be attributed to the use of simplified, low-poly objects focussing on function rather than detail. Consequently making the environment feel more conceptual, possibly hindering participants' ability to fully imagine real-world applications. It was further observed that one of the participants held the HMD to his face in the final revision of the design instead of wearing it on his head which could have influenced immersion and in turn perceived realism.

In contrast, a previous study with flight attendants [6], which had a larger sample size, rated realism much higher (8.4/10). This difference might reflect the varying needs of user groups, with rescue helicopter professionals possibly requiring more visual fidelity. The lower realism ratings in this study could also be outliers due to the small sample size, suggesting a need for further research to confirm these findings.
However, in the early stages of design, achieving high visual realism is not usually necessary. At this phase, the primary focus is on exploring broad concepts and functionality, which requires the ability to make iterative adjustments. Low-fidelity prototypes are especially useful here because they prioritise core functionality over detail. This approach supports rapid ideation and feedback, preventing premature commitment to specific design elements [22].

Further review during the writing process made clear that certain configurations proposed during the workshop, such as an upper patient platform, unintentionally encroached on areas reserved for essential systems like the gearbox systems and and engines. This realisation highlights an important aspect of iterative design in XR. While XR allows users to explore configurations virtually and on a 1:1 scale, it is important to keep engineering constraints in mind from the outset to ensure outcomes are feasible. However, open and free exploration remains important in early stage design to enhance design innovativeness [23], and therefore should be encouraged as much as possible.

5.2 Creativity and Engagement

In figure 24 objects indicated in blue are ideas that came to mind in XR. In white are the ideas from the three-dimensional toolkit.

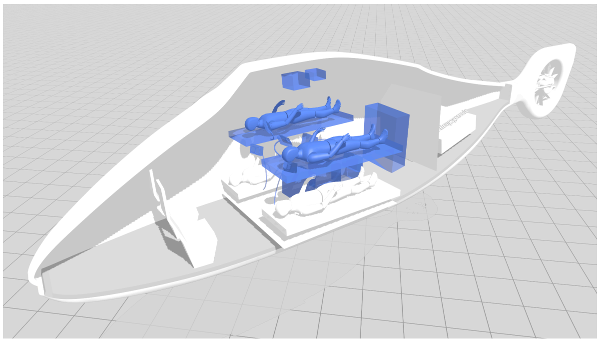

FIG 24. The rescue helicopter design in XR.

It should be noted that this is a conceptual arrangement, intended to stimulate ideation. Placements of objects require adjustment to avoid interference with essential systems, such as the gearbox and rotor controls.

The initial ideas drafted with the three dimensional toolkit did not change in XR but were expanded upon. Both participants rated XR highly for stimulating creative thought (8/10 and 10/10). Novel ideas that emerged during the session were small movable patient monitors, the ability to carry more than two patients and overhead storage. Ideas likely inspired by the scale and freedom offered by the XR environment. Supporting the notion that the immersive nature of XR encourages out-of-the-box thinking, free from the physical limitations of 3D-printed models. However, the engagement and creativity throughout the workshop may have been boosted by the novelty effect of using XR [24]. As discussed by Miguel-Alonso et al. (2021), the novelty effect can provide short term benefits like enhancing engagement, but these benefits may decline as the participants become more familiar with the technology [24]. The novelty effect could explain the high levels of creativity observed in the workshop but future iterations should assess whether this effect persists over time as novelty wears off. Although it cannot be definitively confirmed whether there was a novelty effect present, these high levels of engagement and creativity can certainly be seen as an asset in early-stage design sessions, as the method emphasises iterative, conceptual exploration. Multiple sessions would be needed to determine if the novelty effects persist over time, but the fact that designs can often be laid out in just one session makes this examination less critical.

5.3 Collaboration and Communication

In the XR phase of the workshop collaboration was limited as the study utilised a single headset configuration. This led to only one participant being able to immerse in the XR environment at a time, meaning the participant could only interact with the facilitator and no direct collaboration between the two participants was possible in XR. Consequently, co-design was realised by building off each other's ideas and designs, iterating them one at a time rather than designing them together in real time as done with the three-dimensional toolkit. This could be realised through the monitor projecting the XR room for the other participant to see. This setup highlighted the need for multiple headset to enhance collaboration in the future.
While this arrangement provided insights into individual spatial understanding and design exploration, it restricted the ability to fully assess the collaborative potential of working in XR together. Multiple headsets would have allowed both participants to interact with the virtual environment simultaneously, similar to the three-dimensional toolkit. To assess the differences between the three-dimensional toolkit and XR in terms of collaboration more effectively, a multitude of headsets would be desirable in the future. This could explain why the three-dimensional toolkit was rated high for collaboration (7/10 and 8/10), likely due to the shared, tactile experience it offered. Also, this was the phase where direct collaboration between the participants took place. Communication after the individual exercise at the start of the workshop was in depth and extensive. Factors that were mentioned in the answers of the ‘sensitizing’ questionnaire were brought up during the discussions, suggesting the ‘sensitizing’ successfully primed the participants for the workshop.

5.4 Efficiency, Learning Curve and Transferability

XR aiding the design process in terms of efficiency was rated differently by the two participants: one participant found XR to be highly efficient (8/10) while another rated it lower (4/10). The participant that rated the efficiency lower also had a bigger learning curve, highlighting that the ease of using XR can differ significantly between individuals. This may be due to unfamiliarity with the XR software or not being used to an XR system in general. In contrast, the three-dimensional toolkit provided a more consistent and accessible experience. This could likely be due to the hands-on and interactive nature of the three-dimensional toolkit, which could have a similar effect to LEGO representing abstract concepts physically and being able to manipulate them as discussed in Gauntlett's (2015) work on LEGO as a tool for creative thinking and learning [25].
To alleviate some of the difficulties faced in XR, incorporating haptic feedback gloves that can resemble real world interactions or advanced eye tracking like on the Apple Vision Pro[1] could help bring a 'physical experience' into the virtual environment. The need to rely on controllers would be eliminated and tactile interactions can make the XR experience feel more realistic. Additionally, connecting the three-dimensional toolkit to a system that links the physical objects to the virtual world and updates the designs real time could also be a next step in improving efficiency and easing the learning curve.

6. CONCLUSION

This study explored the application of the XR+ method for the early design phase of a primary rescue helicopter cabin, using the CHASER project as a use case. The method consisted of combining traditional co-creation methods with Extended Reality (XR) and involving end-users of the to-be-designed cabin. It is a co-creation method that can be used in a co-design workshop for the front-end of the design process, bringing end users directly into the design process.

The iterative and collaborative nature of the method demonstrated its potential to engage users early in the design process enabling them to come up with innovative, user-centred solutions. The study results include:

Enhanced Spatial Understanding: XR provided an immersive way to understand the environment

[1]Apple Vision Pro: A spatial computing device made by Apple: https://www.apple.com/apple-vision-pro/

of the cabin and improved the spatial awareness of the participants.

Creative Ideation: The combination of the three-dimensional toolkit with XR simulated creative thinking, leading the HEMS professionals to come up with ideas such as the turntable-like patient loading system and modular patient monitors.

Challenges and Collaboration: A steep learning curve in XR for one participant underscores the need for further refinement of the method. Other limitations such as the need for multiple headsets highlighted areas for improvement in facilitating real-time co-creation in the XR environment.

Balancing Exploration with Constraints: The workshop encouraged free exploration in the physical and XR space. This led to some designs overlooking engineering constraints, highlighting the importance of integrating practical guidelines in the ideation process and striking the right balance between the two.

Applicability Beyond Rescue Helicopters: Despite the small sample size, the XR+ method shows how XR can effectively complement traditional design methods. It offers a scalable framework that shows potential for applicability in other design contexts such as commercial aviation, by involving users early in the design process.

7. OUTLOOK

The rescue helicopter use case provides important insights into the unique needs of medical professionals. However, it is just one of many possible applications for this co-creation method. Given its success in aircraft interiors by engaging users and encouraging collaboration in fields where user-centred design is critical.

Further research is needed to investigate how the collaborative potential of XR can enable participants to easily interact in the virtual environment simultaneously, in a manner that facilitates co-creation. Ideally the setup would not require a facilitator for technical aid. Furthermore, finding a solution that combines the tactile familiarity of the three-dimensional toolkit with the capabilities of XR, in perhaps the shape of a haptic feedback glove, could offer a more intuitive user experience.

Since rescue helicopter workers are difficult to recruit due to limited time, in a previous workshop one participant had to leave due to an emergency [5], an online or hybrid option for conducting the workshop that is not location bound could increase accessibility and participation, similar to the set up by Reimer et al. (2023) which was done entirely remotely [5]. This could not only address participant limitations but could also open the door to further understanding how XR+ could be applied remotely.

XR+ allows for rapid exploration and iteration with users providing them the opportunity to lay out the most important functions of a cabin in a matter of hours. This input can in turn serve for further design exploration. Further research could investigate how this approach can be applied to other complex environments in aviation, such as commercial aircraft cabins or urban air mobility vehicles. Exploring the integration of XR+ in follow-up studies could further enhance its effectiveness and scalability, making the design process more efficient and user-centred.

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