Mixing Realities:
Combining Extended and Physical Reality in Co-Creative Design for the Galley of the Flying-V

Master Thesis
Integrated Product Design
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Master Thesis
Delft, July 2023

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Preface

This graduation report marks the culmination of my Master's thesis Integrated Product Design (IPD), at Delft University of Technology (TU Delft). It builds on the groundwork laid out by the German Aerospace Center (DLR) located in Hamburg.

The original assignment drafted by TU Delft and DLR sought to explore how VR can shape the interior of the Flying-V. However, as I merged my own interests with the interests of DLR and the TU Delft, the scope of the project shifted. The goal became to explore the possibilities of using Extended Reality, an umbrella term for Virtual, Augmented and Mixed Reality (VR/AR/MR) and co-creation. Two topics I was not familiar with when starting my thesis but was, and still am, highly interested in.

The testbed to explore these themes became the to-be-designed galley in the Flying-V. This proved to be a fertile testing ground since it allowed for the opportunity for the cabin crew of KLM to be involved in the design process. Since a lot of projects mainly focussed on passengers this was a target group that has not been given a lot of attention yet in the design of the Flying-V. It was an exciting opportunity to let them be part of the Flying-V.

The research is situated at a crossroads of the emerging technology of XR (since starting my thesis, three major new XR devices have either been announced or released) and the practice of co-creation in design. The unique design of Flying-V proved to be an innovative and exciting platform to investigate end-user participation in combination with co-creation.

The flight attendants joining the co-creation sessions brought valuable insights into both how they would like their galleys to be, but also in terms of how to conduct a co-creation session with XR. I hope this thesis can be a tiny building block in integrating technology into the design process and provoke further expiration in this evolving domain.

Enjoy reading!
Sebastian Cornelje

Acknowledgements

This project would not have been possible without the many people helping me along the way. I want to thank my supervisors for being great partners and just genuinely nice people. Peter, thank you for your valuable insights, literature recommendation, ideas and all questions I had regarding aviation. Also, for introducing me to your contacts and connections in the aviation industry. These proved to be instrumental in shaping the project and not to mention your endless supply of enthusiasm regarding the topic!
Froukje, for the good sparring sessions we always had and your razor-sharp mind in pinpointing the exact topics that needed tackling at particular times. I appreciate the insights you always gave me and the knowledge you have about co-creation, it always felt like I got a lot smarter after speaking with you. Besides that, it was also fun just having a casual off-topic chat when we felt like it!
Fabian, for introducing me to and guiding me through DLR. Without you, this would have been a lot harder. Thank you for supporting me throughout the thesis and making sure everything I needed was in place, and providing help where you could. Plus, checking in with me throughout this journey, either work or non-work related! It was great to have you as a company mentor.
Also, a thank you to colleagues at DLR who helped and participated in the pilot workshop, which laid out the foundations for the sessions to come.

I would like Sandhya for sharing your expertise regarding VR, contacts with KLM and updating me on your research. It was always nice to work and talk with you whenever I had questions regarding VR. It was a bonus to see our research overlapping in certain places. Good luck with your PhD!
I want to thank all the KLM flight attendants that joined the co-creation workshops. It was a pleasure to work with all of you. Some of you almost convinced me to become a flight attendant myself! A special thank you to Anouk, Terry and Melissa from KLM who were instrumental in making this happen and helped recruit flight attendants. If it weren't for you I'd probably still be searching for participants.
Thank you, Daniel, for providing me with early Flying-V models to test some quick designs with thanks to Lisa for providing me with her model to further test and prototype.
I want to thank everyone at the XR Zone in Delft. You guys were welcoming from the moment I first walked in. Without the helpful staff there, I could not have done the research I needed to do. It was great being able to ask for help and assistance and to borrow the amount of headsets that I did and drag them along with me.
A special thanks to Melissa, who was a great friend and sparring partner throughout my thesis. It was great having you there as a second facilitator at one of the workshops, and this definitely led to insights I would have missed if you weren't there. Thank you for your unconditional support!
I'd like to thank all my friends inside and outside the faculty who supported me during my thesis time. It was a long time coming, and you guys knew the significance of me doing my graduation project after thinking about doing it for so long. You all know who you are! And also a special thank you to all my friends that visited me in Hamburg while I was living there during my project.
Last but not least, I'd like to thank my parents and brother for their everlasting and unconditional support, couldn't have done it without you!

Contents

Executive Summary

This thesis explores combining Extended Reality (XR) with traditional co-creation methods to construct a unique and integrative design facilitation method named XR+. The XR+ method is intended to be used at the German Aerospace Center (DLR) to aid in the process of innovative cabin design. However, the method is not limited to cabin design and can be applied to various design cases.

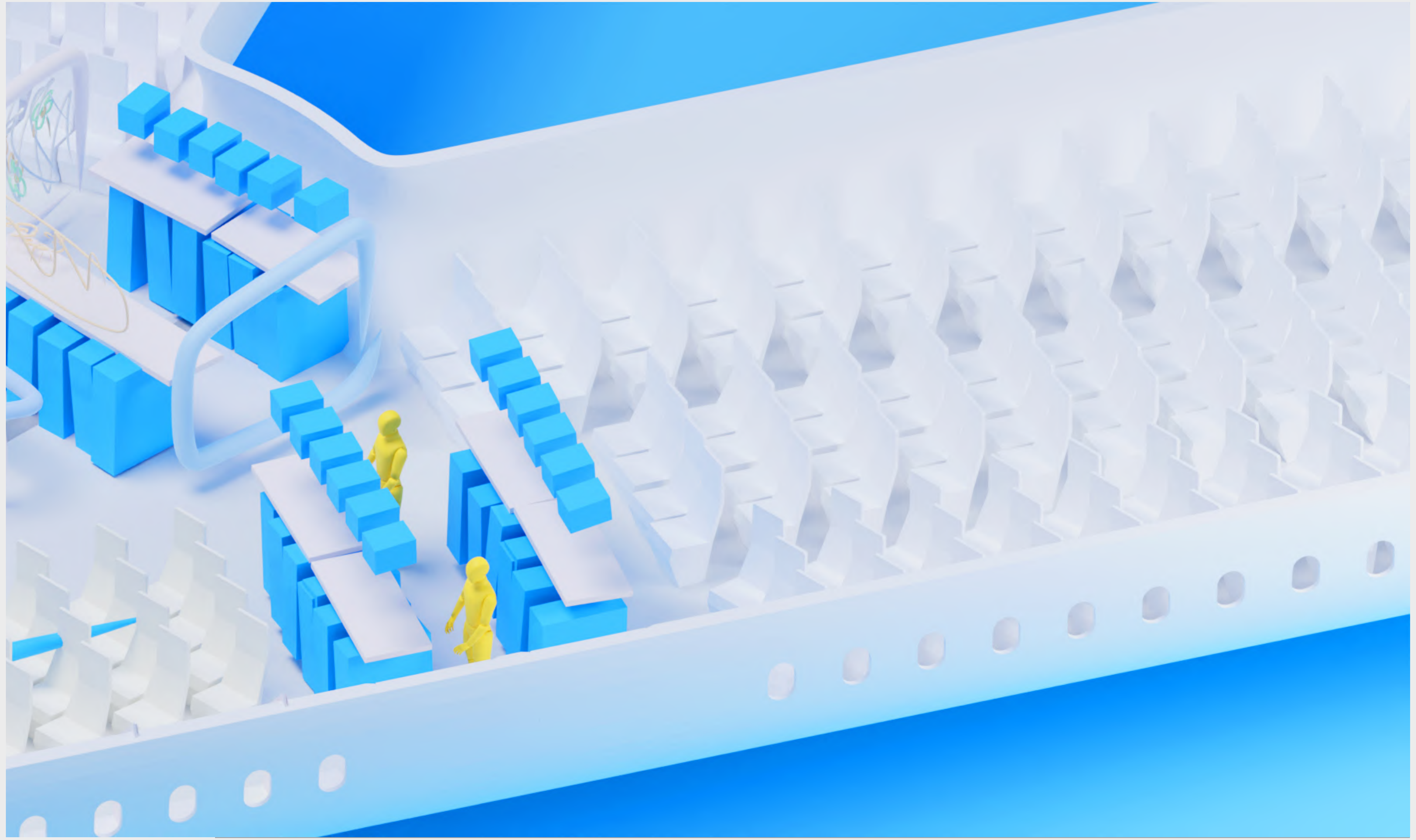
This method came to be by uniting a multitude of factors, namely: The Flying-V aircraft, galley design, traditional co-creation methods and the immersive potential of XR technology. The choice to work with the Flying-V aircraft as a case study was intentional. The absence of a predefined galley design presented a unique opportunity to develop and test the XR+ method.

Design, in this study, leans heavily on the collective problem-solving capabilities brought to the table by participants when engaging in co-creation. This is key for addressing issues too complex for individuals alone. It resonates with the insights of Sanders & Stappers (2006), who highlighted a shift in the design process towards collective, future-oriented design practices. Given that XR has gained significant popularity in recent years and found its way into the design world, it seems pertinent to explore how this technology can be combined into a method with these collective, future-oriented design practices. The first step for this was taken by DLR in a paper exploring XR for the cabin design process.

The journey towards a design method combining co-creation and XR were significantly influenced by collaborating with KLM cabin crew. In total, five co-creation workshops were held, each dedicated to galley design for the Flying-V, and each serving as an iteration to refine and integrate the XR+ approach within co-creation methodologies.

The workshops highlighted the unique strengths of both traditional co-creation and XR. As part of traditional co-creation, participants found physical elements, like blocks, easy to use and effective for initiating conversation and generating ideas. Once these initial concepts were built using 1:20 scale physical objects, the immersive environment of XR was introduced to further explore these concepts on a 1:1 scale. After immersing in XR, practical aspects of the initial physical design were brought to the forefront. Additionally, XR created a new spark of engagement and new creative possibilities were opened up, especially when participants took turns being in XR, creating a sense of curiosity in the non-immersed participants and wanting to be part of the immersion. Taking turns immersing led each participant to build on to the idea of the previous participant, each participant 'hitchhiking' onto each others' ideas.

It was found that where idea generation stops in the physical world, it continues in the virtual world—highlighting the unique strengths of both traditional co-creation and XR.
The conclusion of this research presents a guide for DLR and other design stakeholders to integrate XR+ into their design processes and to use as an add-on to their current practices. Integrating traditional co-creation elements with XR stimulates ideation, deepens understanding of user needs, and leads to the discovery of innovative design solutions.



Introduction.

1

1.1 Background & Motivation

Whilst the environmental impact of air travel is more evident than ever (Hemmings, 2018), flying is becoming increasingly popular every year. Airbus predicts that the demand for passenger traffic will annually grow by 3,6% over the next 20 years (Airbus, 2022). The Asia-Pacific market is expected to be the fastest growing in terms of airline activity (Aviation Business News, 2019). The expansion and growth of the air travel sector are making aviation one of the fastest-growing sources of greenhouse gas emissions (European Commission, 2022).
They will hence conflict with the climate goals that have been agreed on in the Paris Agreement (Graver, 2022). According to TU Delft Aerospace faculty Dean Henri Werij: "Ultimately, we have to fly entirely on sustainable energy. CO2-neutral" (TU Delft, 2021)

The International Air Transport Association (IATA) has committed itself to "make flying net zero" by the year 2050 (IATA, 2021) by passing a resolution for IATA member airlines to commit to making their operations net-zero carbon for 2050. IATA defines four main areas for achieving this goal, namely: sustainable aviation fuel (SAF), new technologies, infrastructure/operations and offsetting/carbon capture. Within the realm of new technologies innovative propulsion technologies for aircraft are included: fully electric, hydrogen and hybrid-electric. However, also new aircraft designs such as canard wing, blended wing, flying wing and strut or truss-braced wing (IATA, 2022).

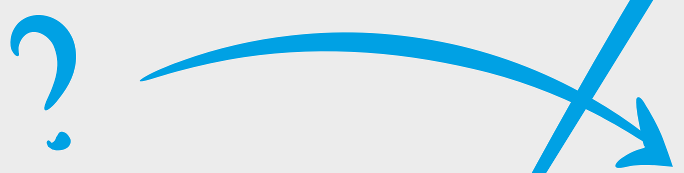
One such attempt to make aviation more sustainable is the TU Delft research project named Flying-V. In collaboration with Airbus and KLM, they are developing an aircraft that results in a 20% fuel efficiency compared to today's most advanced aircraft the Airbus 350.
With this radical new design comes room for rethinking what it means to fly in the future, in the broadest sense. Unlike a traditional tube-and-wing aircraft the Flying-V differs substantially in shape from what one might be used to seeing regarding current aircraft. This fact leads to exciting new opportunities for redesigning aircraft elements from scratch.

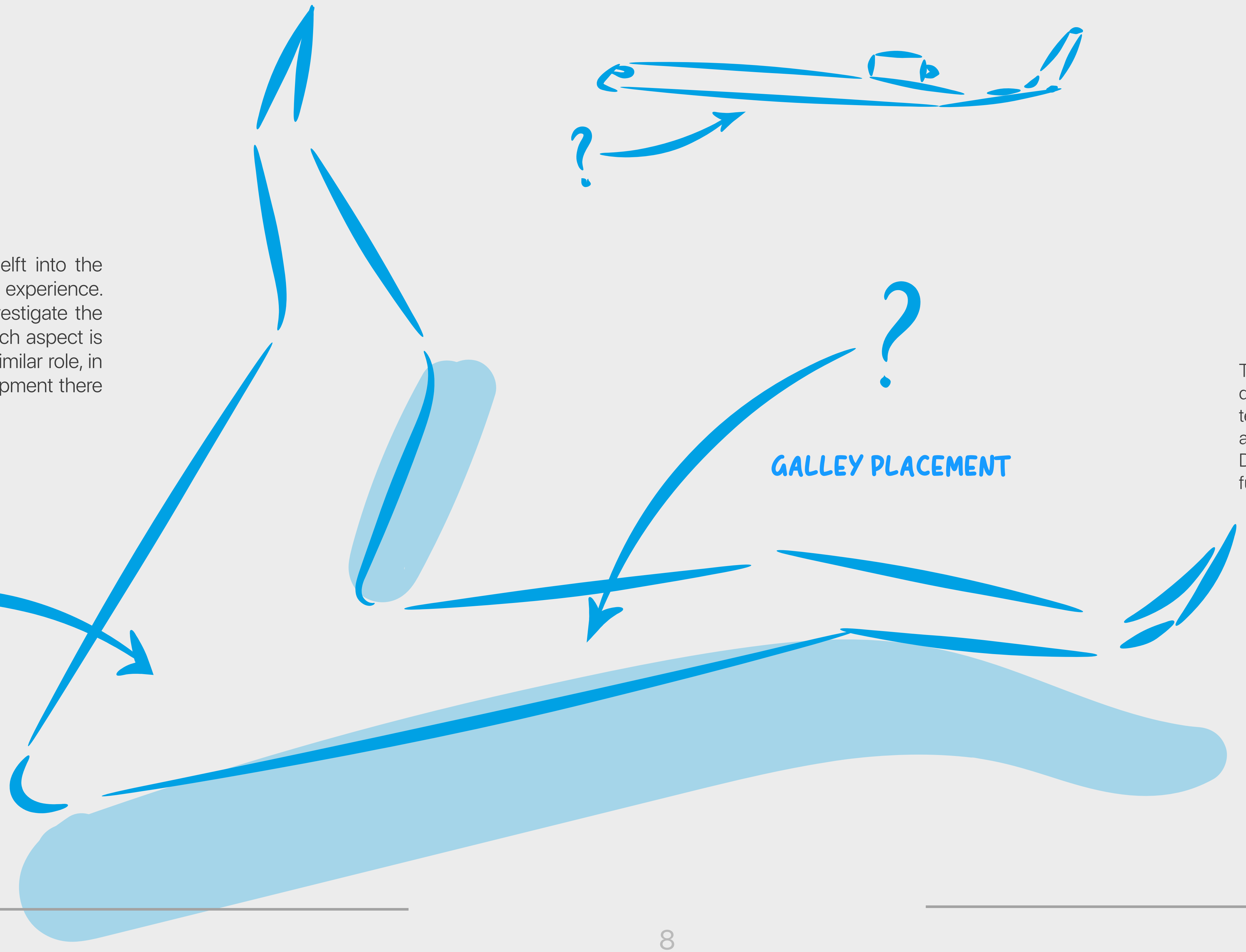
Fig.1: The Flying-V

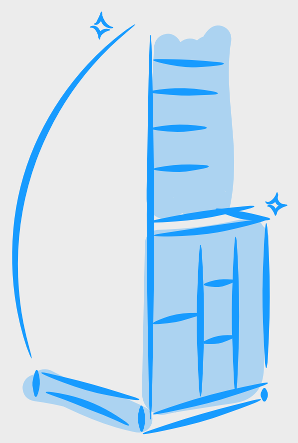
This brings us to the role of the faculty of Industrial Design Engineering (IDE): They are responsible for the design of the interior of the Flying-V. Numerous (graduation) projects have been conducted in designing and investigating various parts of the interior. Apart from the collaborating parties above, the German Aerospace Center (DLR) is also exploring innovation in cabin design—specifically, innovative new ways of designing cabins. According to experts at DLR, the aircraft industry is a conservative industry where change is hard to implement due to rules, regulations and safety certifications (Moerland-Masic, personal communication, 2022).

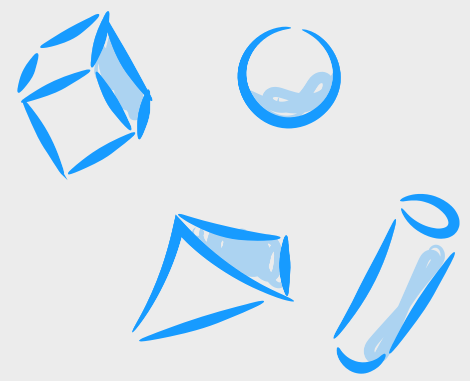
Due to this stubborn nature, it is hard to innovate in such a tight space as an aircraft cabin. The procedures now are timely and costly and require a lot of meetings, steps and iterations (Moerland-Masic, 2021). The cabin design is now approached with a so-called "shot in the dark" based on identified wants and needs through customer surveys and questionnaires. Hence DLR is looking into more novel and innovative ways to go about designing the aircraft cabins of the future. This is where their interests come together with the interests of the TU Delft and designing the Flying-V.

Until now a large part of the research at TU Delft into the Flying-V has focussed on the passenger experience. However, there are still large opportunities to investigate the role of the cabin crew in this new aircraft. One such aspect is the design of the galley, or something fulfilling a similar role, in the Flying-V. Since the aircraft is still in full development there is much space for ideas and concepts to emerge.



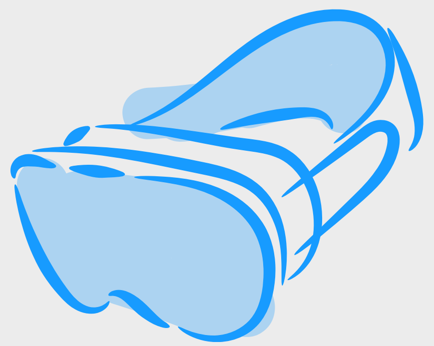






This thesis will explore a novel approach to the challenge of designing the Flying-V's galley using Extended Reality (XR) technologies and physical elements in a co-creation process. This approach will mainly involve DLR & KLM, with the goal of facilitating DLR in a method to come up with innovative cabin concepts in the future and their future projects.

KLM cabin crew is involved in creating this method and used as a testbed to iterate on this method. The cabin crew are primary users of the galley on board an aircraft and hence are the experts in their own experience of using a galley. By combining physical and virtual elements that represent the proposed design, the aim is to draw on their expertise and co-create an aircraft galley that is efficient and user-friendly and could provide inspiration for the final galley design in the Flying-V.



1.2 Problem Definition and Goals

The main problem this research aims to address is how and where to use XR in the co-creation process whilst involving end-users and their feedback in this (early) design stage. The XR terrain is shifting rapidly in the industry (Frolova, 2023) and as a result, companies wanting to adopt XR in their portfolios are confronted with barriers. They might not have access to the needed human resources, or they only use tools that require minimal training, therefore, missing out on the full potential of this technology. (Di Lucchio, Imbesi, Diaz Morilla, 2021)
The goal of this study is to integrate XR within a co-creation process in a way that is workable and replicable for the facilitator and the participants of the session. Adding XR to the co-creation process is hoped to enhance the co-creation process in such a way that DLR can use this way of working in future sessions. Galley designs emerging from this way of working are considered a bonus but not the main aim of this research.

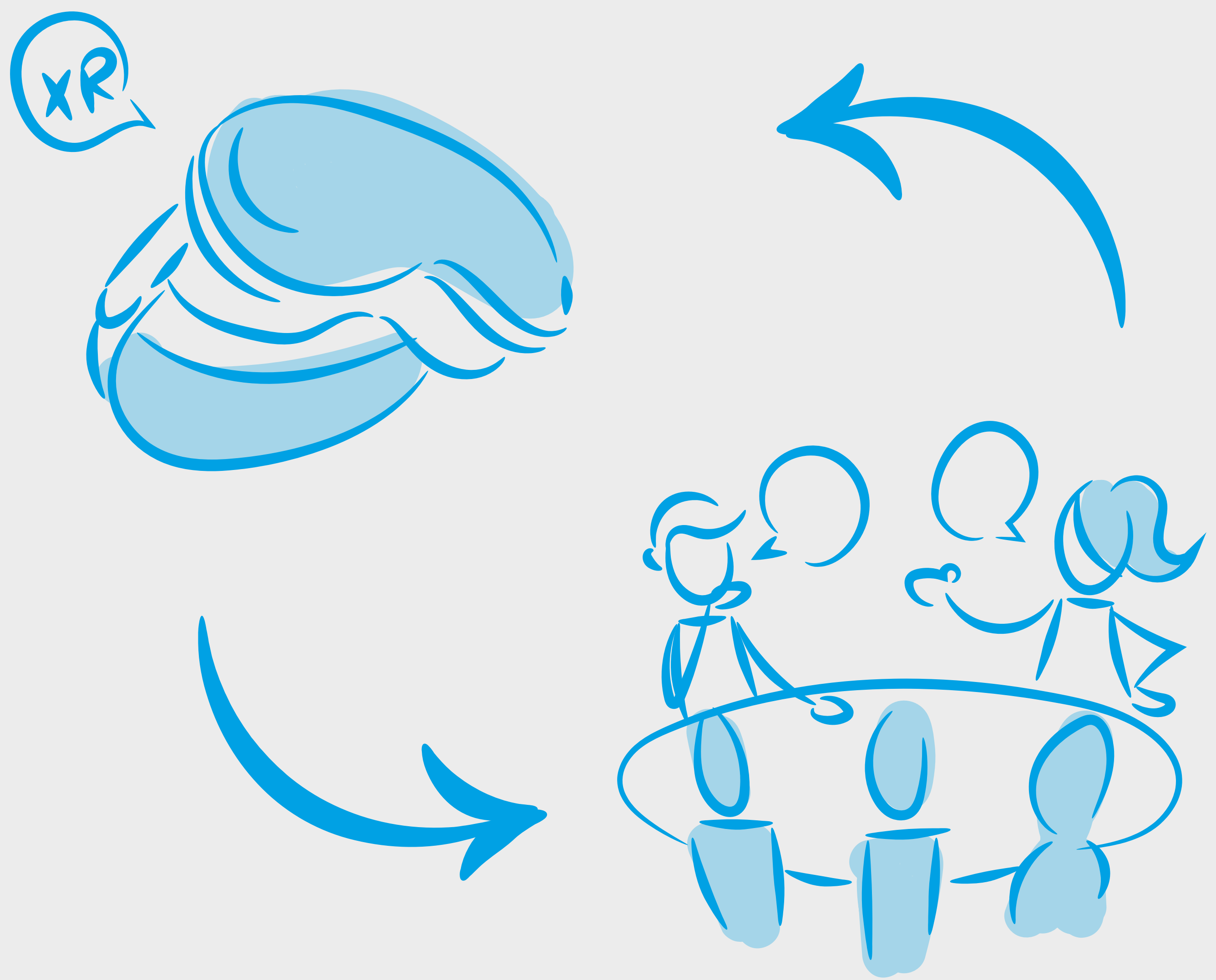


Fig.2: Gravity Sketch being used at ArtCenter College of Design to view a Jeep Wrangler

Exploring the Context

2

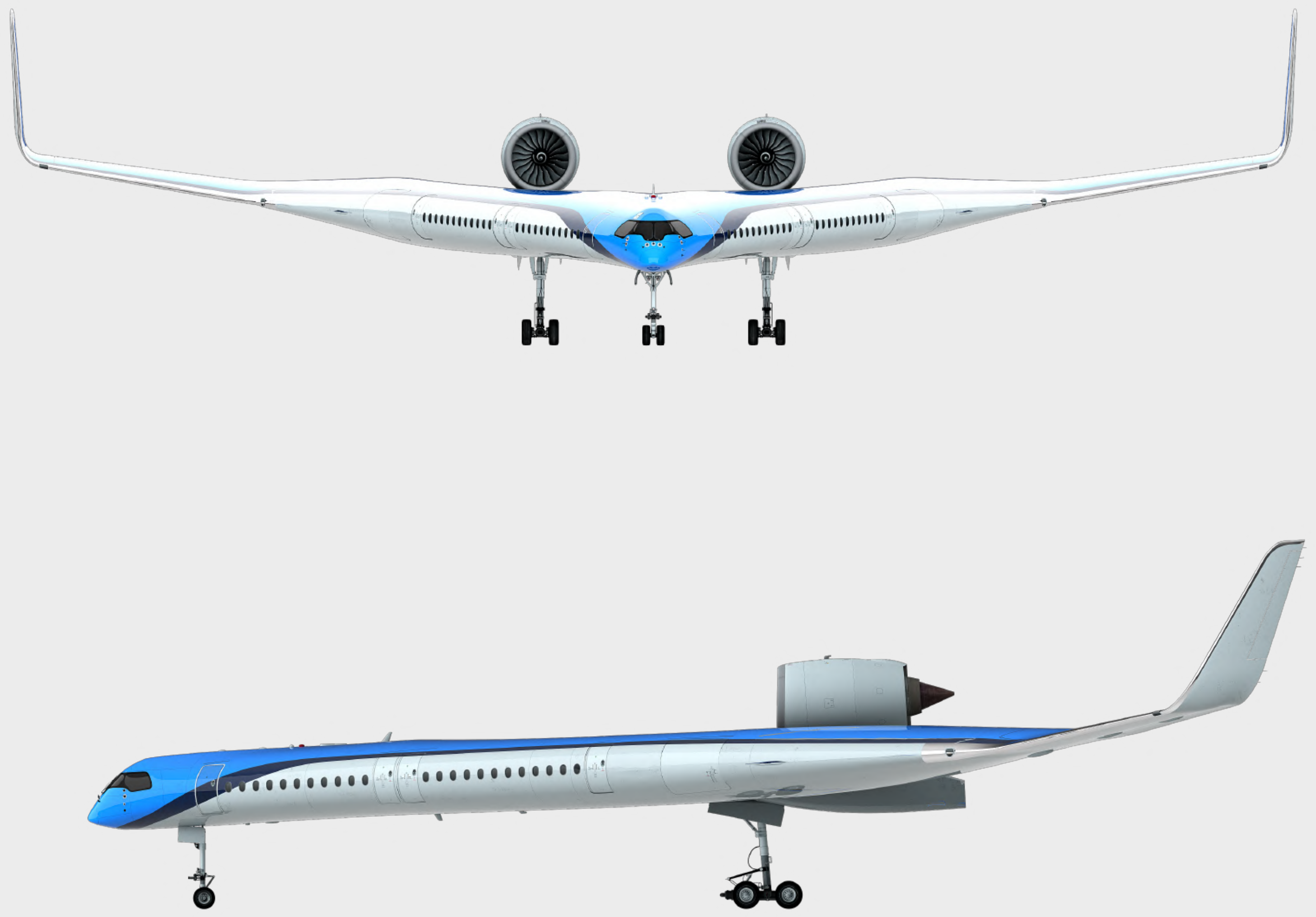
This thesis aims to bring together a multitude of dimensions that all come together that aid in developing a recommendation on how to use XR and co-creation. To successfully test and experiment with a method: The Flying-V. The Flying-V will be used to test this new way of working with XR and co-creation. More specifically, the research will focus on the to-be-designed galley of the Flying-V. A good test case will make for an excellent basis to iterate on (P.J. Stappers, personal communication, October 11, 2022).
Because the reader may be unfamiliar with the terms, the following paragraphs will separately introduce the subjects that come together in this thesis. The end of the chapter will explain how they come together. The following section will explain the concept of the Flying-V, secondly the galley, thirdly co-creation and lastly, XR technology.

Fig. 3 The Airbus A350

2.1 The Flying-V

The Flying-V is one of TU Delft's research lines into making aviation more sustainable. Developed initially by Justus Benad during his thesis at Airbus in Hamburg, the Flying-V is a radical redesign of what a long-distance commercial aircraft could look like in the future. The Flying-V is a design for a highly energy-efficient long-distance aeroplane. It integrates the passenger cabin, cargo hold and fuel tanks into a distinct V-shaped fuselage. This flying-wing aircraft can carry roughly the same amount of passengers as an Airbus A350 whilst having the same wingspan but a shorter length. This allows it to use current airport infrastructure such as gates and runways. The improved aerodynamic shape and reduced weight compared to regular aircraft results in a 20% reduction of fuel compared to an Airbus A350, today's most advanced aircraft (TU Delft, 2021)

Along with reducing environmental effects, the aircraft's distinctive design offers chances for the creation of new concepts that enhance or reimagine the passenger and crew experience. The V-shape calls for radically new ways of rethinking of how a cabin interior can be designed. Improvements in seating, floorplan design, lavatory design, galley layout and VR experiments have been conducted and/or are in development. (Yao (2019), Vink (2020),Lam (2020), Wamelink (2021), Houwing (2022)). A substantial part of this thesis is themed around the latter two subjects.



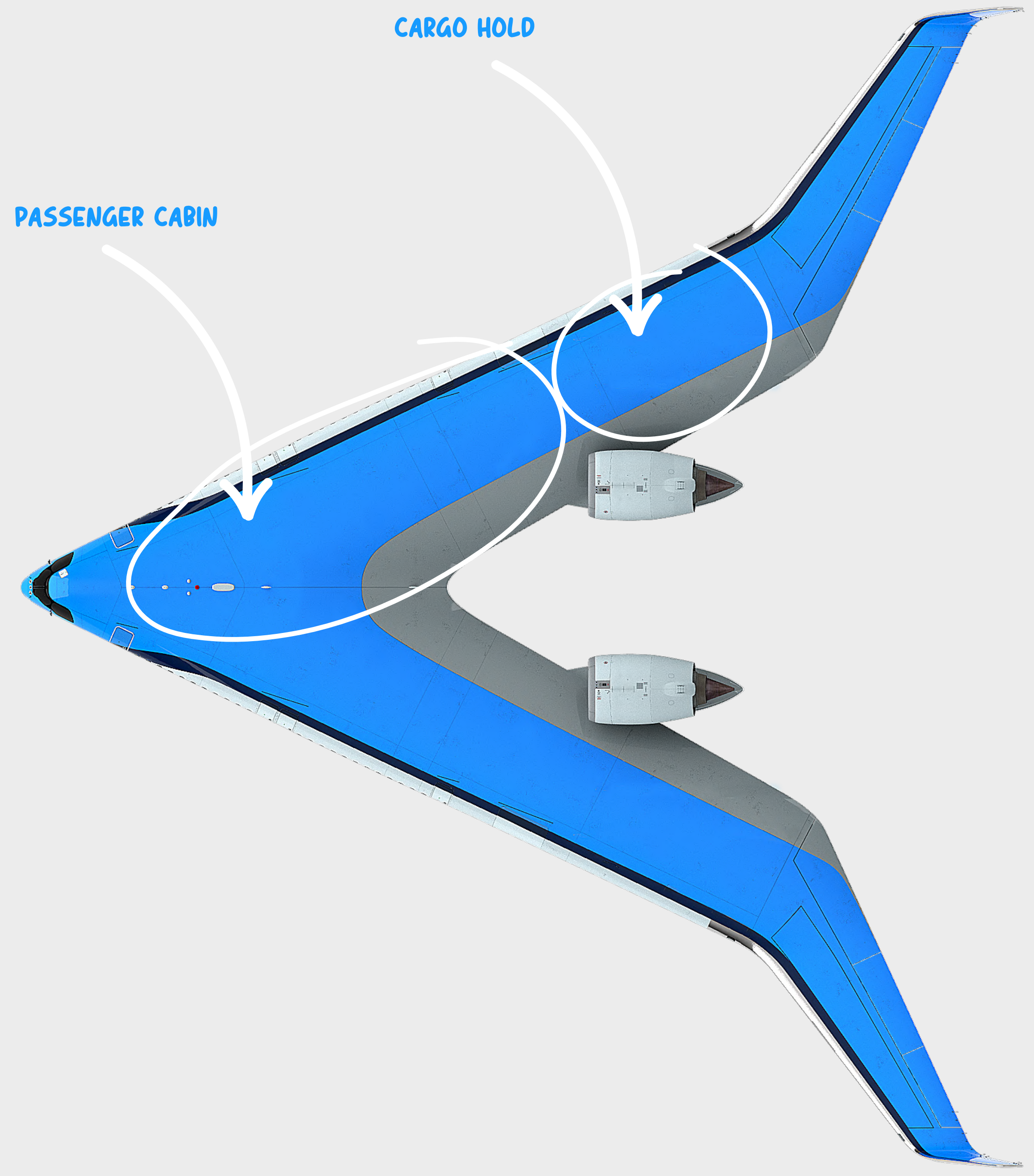


Fig. 4: Schematic view of the Flying-V

2.2 Introduction to the Galley

The word galley refers to the kitchen in a ship or aircraft. In this thesis, the galley will only refer to the kitchen inside an aircraft. Currently, the galley is a fixed monument in the aircraft that contains different types of equipment to prepare, store and serve food and drinks. There is a distinction between wet and dry galley. Wet galleys are used to store and prepare food or drink & are connected to systems such as potable water and waste systems, air extraction, cabin ventilation and power supply. Dry galleys are not connected to any system and are used for storage. (Cremers, 2020)
The size of the galley varies between the type of aircraft and the location inside the aircraft. Galleys are usually placed in the front and rear of the aircraft with bigger aircraft having galleys in other sections too. They mainly consist of standard equipment that is configurable to the desired layout of the airline. They are tailored to the airlines' standardisation and have a primarily industrial, functional appearance (Lam, 2020).

"The Flying-V will bring fundamental changes to the interior of an aircraft. However, this has consequences for the onboard services" (Lam, 2020). The design of aircraft galleys plays a critical role in the overall passenger experience, cabin crew workflow, and aircraft efficiency. Considerations to include are the galley's size and layout, the placement of equipment, storage and ease of movement for the cabin crew.
Typical items found in a galley include but are not limited to trolleys (full-size and half-sized), convection ovens, chillers, coffee makers and water boilers, storage units, trash compactor and waste bins, sinks/gutters or water systems, emergency equipment. A short description of each item will be given:

Fig. 5: An overview of a typical galley

Fig. 6: KLM's Boeing 787 Dreamliner Economy Galley

Trolleys: Meal carts or trolleys come in a variety of sizes due to different standardisations. They are mostly made from aluminium. The most commonly used standard is the so-called ATLAS standard. Named after the founders: AirFrance (A), TAP (T), Lufthansa (L), Alitalia (A) and Sabena (S). Full-size trolleys of this standard are 301mm in width, 810mm in depth and 1030mm in height with doors opening on both sides. A trolley typically weighs 15 kg when empty and up to a 100KG when loaded. Half-size trolleys are 405mm in depth and open on one side of the trolley. (Lam, 2020) In addition to the ATLAS standard, the KSSU standard is the second most used. Named after: KLM (K), SAS (S), Swissair (S) and UTA (U). It is 3mm wider than the ATLAS standard and the standard used by KLM (Standards & Norms, 2017). Trolleys are typically designed with adjustable shelving or compartments allowing for the holding of different-sized items.

Ovens: Food in the galley is heated through convection ovens. Rather dan cooking from scratch they are designed to reheat pre-cooked food provided by catering service on the ground. They use convection heating for even heating and newer models may also have a steam function like Safran's Concert Steam and Convection oven. Ovens are loaded with oven inserts on which the trays with meals are distributed.

Chillers: For keeping food and beverages cold mainly by blowing air through the compartment, or through similar techniques as with regular refrigerators by vapour-compression cycle.

Coffee Makers: As the name says these make coffee and can come in various models for different types of coffee like espresso, filter and capsule coffee maker

Water Boilers: These galley inserts provide hot water for the making of tea or other needs. Some airlines use the warm water to heat hot towels for their passengers.

Containers: Galley containers usually come in two sizes with the most common being depicted above. These containers are used for storing and transporting food, beverages, and other in-flight service items. Similar to the trolleys, galley containers also come in different standards like ATLAS and KSSU.

2.3 Co-creation

The third central theme of this thesis involves co-creation and together with XR lays at the heart of the method of that what will be designed. In design, co-creation has different definitions that vary slightly from each other depending on the institution. (Mattelmäki & Sleeswijk-Visser, 2011) However, co-creation is widely understood as "practices where a design practice and one or more communities of practice participate in creating new desired futures" (Lee, 2018).

In ID-StudioLab, a design research community within the faculty of Industrial Design Engineering, the term co-creation has been used when users are 'stepping into the shoes of designers' and are given tools to create new ideas and are facilitated in this process by designers and researcher (Mattelmäki & Sleeswijk-Visser, 2011). In this thesis co-creation will refer to the act of users, in this case designers from DLR and cabin crew members from KLM, creating new ideas amongst themselves whilst being guided by a designer, the author of this thesis. This idea is rooted in the concept of Participatory Design (PD). PD is a design approach that actively involves the (end) user in the design process to ensure their needs are met (Sanders & Stappers, 2012).

A keyword in PD is 'empowering', meaning that the people affected by the design should have the power or possibility to influence the design. They are also seen as valuable contributors by offering their expertise and knowledge throughout the process. (Mattelmäki & Sleeswijk-Visser, 2011)

The challenge in co-creation is usually who to involve in the process and how to open the process for those affected by the outcome. Another challenge is supporting a setting that fosters people's collective creativity (Lee, 2018). For the former matter, the choice was made early on to strictly involve cabin crew in the process since up until now the focus for the Flying-V research has mainly been on passenger experience. The challenge now lies in fostering the collective creativity of the cabin crew. Iterative attempts to how this is done will be explained in chapter 5.

Co-creation sessions can take various forms, from structured workshops to utilising techniques like sketching and physical prototyping to role-playing and scenario exploration. The method chapter of this thesis will go into more detail about how the co-creation sessions have been set up for this case.

Fig. 7: Examples of a co-creation session courtesy of Waag futurelab, SISCODE & InventAir.

2.4 'Extended Realities'

The term "Extended Reality" (XR) refers to a computer-generated simulation that users can experience. It encompasses any sort of technology that modifies reality by incorporating digital elements into the real-world environment, or completely virtual environment, blurring the distinction between the physical and the digital worlds. (Tremosa, 2023) Extended Reality is furthermore an umbrella term encompassing Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). Each of these 'realities' share common features and requirements but have different purposes and underlying technologies (Arm Blueprint Staff, 2022).

Fig. 8: XR as an umbrella term image courtesy of El-Jarn & Southern

What is reality?

Many people, from writers and scientists to philosophers and artists, have defined reality. Albert Einstein defined reality as: "Reality is merely an illusion, albeit a very persistent one." German philosopher Friedrich Nietzsche implied a more subjective aspect "There are no facts, only interpretations.". To an extent, the way we process information and construct reality is unique to each of us and dependent on previous experiences, genetics etc. This in turn shapes how we perceive the world. (Tremosa, 2023). An example of this is how different people can perceive the same colour differently. For instance, are tennis balls green or yellow?

To understand XR we must understand reality as a construct every individual makes from their senses, whether they come from the physical or digital world. While wearing an XR head-mounted display (HMD) one can feel as if they are present in a completely digital environment. The digital information perceived by one's senses makes it feel as if one is present in the virtual world.

According to neuroscience, the brain creates an embodied simulation of the body in the world to regulate and control the body effectively. This simulation represents and predicts actions, concepts and emotions. It is used to predict upcoming sensory events both inside and outside the body and the best action to deal with these events (Barsalou, 2004)

XR with an HMD works similarly. The XR system tries to predict the sensory consequences of the movements made by the user wearing this HMD (Riva et al., 2019). This ensures the user sees the same scene as would be seen in the real world. XR can deceive the brain's predictive coding systems, producing the sensation of presence in a virtual body and the digital area around it. Hence, XR can be defined as an "embodied technology" for its ability to modify the embodiment experience of its users (Riva, 2008)

The reality-virtuality continuum

The reality virtuality continuum (Milgram, Takemura, Utsumi, Kishino, 1994) is a theoretical framework that can aid in understanding the full range of XR technologies. It spans from the physical or real world to the entirely virtual or digital enviroment. Or as can be seen in the figure 9 from the real to the virtual environment. On this continuum, the different technologies VR, AR and MR exist.

These three terms and the umbrella term XR fall into the category of so-called spatial computing. This definition was coined by Simon Greenwold from MIT (Greenwold, 2003). Greenwold describes spatial computing as follows: "Spatial computing is human interaction with a machine in which the machine retains and manipulates referents to real objects and spaces. It is an essential component for making our machines fuller partners in our work and play."

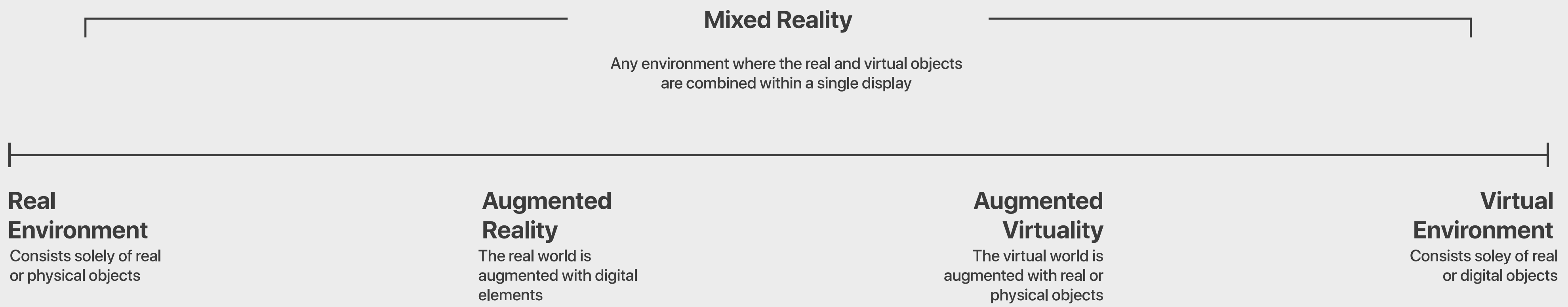


Fig. 9: The reality-virtuality continuum adapted from Milgram (1994)

What is VR?

Virtual Reality or VR is a complete immersion in a digital experience or virtual environment. It immerses the user in a completely computer-generated world removing them from reality. (Billinghurst, 2017) The physical or real world is completely blocked out. "VR experiences are located at the virtual extreme of the "virtuality continuum" (Tremosa, 2023). Tremosa adds that these experiences in VR can feel real although users are aware they are not since humans construct reality from the information they receive from their senses. This is because ownership of virtual limbs and bodies from the user may engage in the same perceptual, emotional, and motor processes that make us feel that we own our biological bodies (Slater et al., 2019). The more coherent the information is provided to our senses, the more immersive the experience will feel.
This is particularly important for a few features with a larger effect on feeling present in the virtual world. They are defined as being the most important in making the virtual world believable, these are tracking level, stereoscopy and field of view (Cummings & Bailenson, 2015) They have a more substantial impact on user presence than audio and visual quality.

Tracking level in XR refers to the ability of the system to monitor and adapt to the user's movements in real-time and to know what direction a user is facing at any given moment. (Gellert, 2017)
Stereoscopy is a technique to create or enhance the illusion of depth in an image. This is done by providing two slightly off-set images to the right and left eye. The brain combines these into a three-dimensional image (Afifi, 2017)
Field of view (FoV) is described by Ball et al. (1988) to be " the visual area in which information can be acquired within one eye fixation."

Fig. 10: Mark Zuckerberg wearing a Meta Quest 3 headset

What is AR?

As stated by Azuma: "AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it" (Azuma, 1997) This means AR is a hybrid of virtual and physical elements. The virtual elements are only layered on the physical world and do not interact with them. AR is close to the physical world on the virtuality continuum.

What is MR?

The term mixed reality can be traced back to 1994 when it was first used in the context of computer interfaces. The paper written by Milgram and Kishino Mixed Reality is defined as: "..a particular subclass of VR-related technologies that involve the merging of real and virtual worlds." MR involves the blending of physical and digital worlds along the 'reality-virtuality continuum'. Users can see and interact with both virtual and physical elements. "MR experiences get input from the environment and will change according to it" (Tremosa, 2023)

Fig. 11: IKEA's AR Smartphone Application

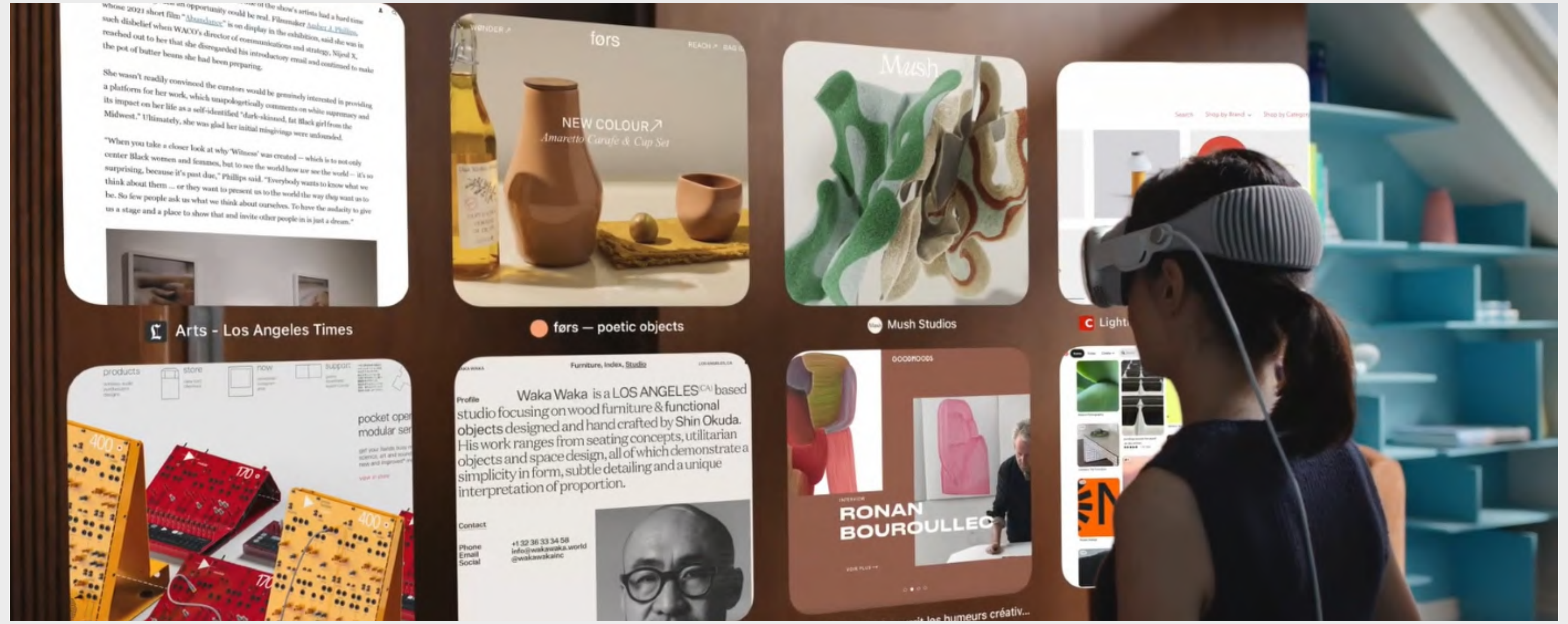


Fig. 12: Demonstration of Apple's Vision Pro

2.5 Connecting the Dots

This thesis combines the seemingly disparate elements of galley design in the Flying-V, co-creation and XR technology. Co-creation allows for a diverse range of ideas, needs and potential solutions to emerge by including end users, designers and other stakeholders in the process. Since the application of XR is becoming more popular, there is a growing body of literature being created linking it to other cases than the previous most popular category: gaming. Hence more research is also being done into linking XR to co-creation. The COVID-19 outbreak has accelerated collaboration technologies including the possibility to collaborate in XR. However, these technologies are still considered to be relatively novel and have not been widely adopted yet amongst consumers and enterprises. Deloitte states that XR's future growth will depend on applications that take full advantage of the immersive medium and encourage repeat usage, which is possible when used as a co-creation tool.

They further state that for enterprise uses, XR's opportunity lies "in simulating work experiences, visualising enterprise and industrial-scale systems, and overcoming the challenges of distance." In the context of participatory design and co-design, XR can facilitate more effective and interactive collaboration sessions. Designers and stakeholders can virtually inhabit the same design space, exploring, adjusting, and experiencing the design from all angles and in real-time (El-Jarn & Southern, 2020). This thesis argues that the power and benefits of both XR and co-creation must be used in symbiosis to create a combination that benefits all stakeholders in the design process. The next chapter will outline this in more detail.

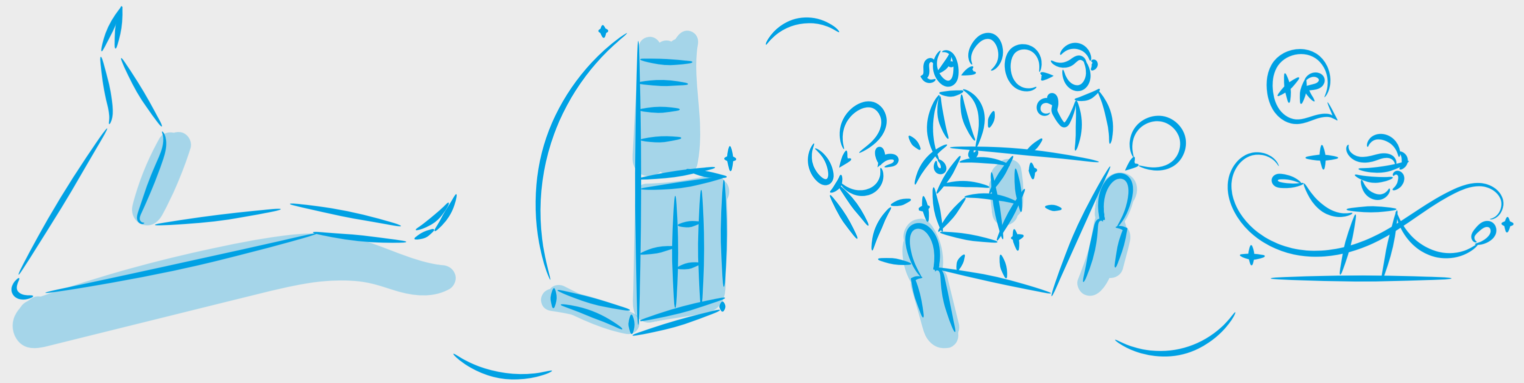


Fig. 13: The subjects that come together in this thesis

XR & Co-Creation

3

3.1 A shift in the design landscape

In the past five decades, the design field has experienced dramatic changes (Voute et al., 2020). There has been an expansion from the 'traditional' product design profession concerned with making products all the way up to design on the systemic level, tackling societal challenges, behaviour changes and sustainability. (Voute et al., 2020)

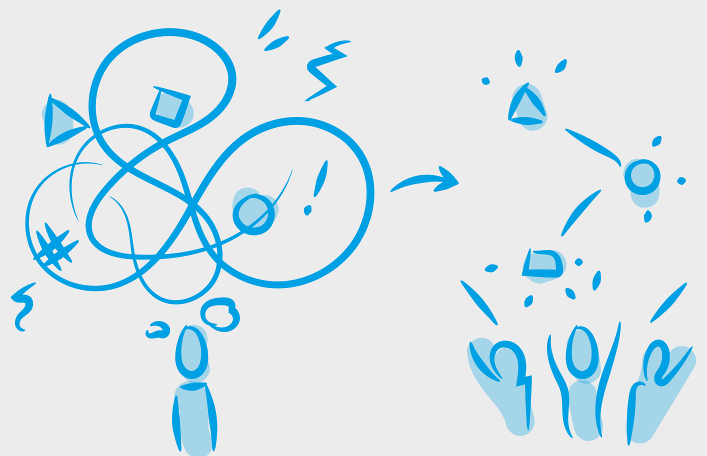
According to Sanders (2010), the changing landscape of human-centred design research has influenced the design practice. The user-centred design method, which began in the 1970s and gained popularity in the 1990s, proved to be the most effective for creating consumer goods. However, it is becoming apparent that this method cannot tackle the scale and complexity of today's challenges (Sanders & Stappers, 2006). Sanders & Stappers mention that designers are no longer designing products for users, but they are: "designing for the future experiences of people, communities and cultures who now are connected and informed in ways that were unimaginable even 10 years ago". There is a shift from the design of categories of 'products' to designing for people's purposes demonstrated in this table from 2006 by Sanders & Stappers.

Table 1. A snapshot in time of traditional and emerging design practices.

The traditional design disciplines focus on the **designing of** 'products' …	… while the emerging design disciplines focus on **designing for** a purpose
visual communication design	design for experiencing
interior space design	design for emotion
product design	design for interacting
information design	design for sustainability
architecture	design for serving
planning	design for transforming

The technology or product is at the heart of the conventional design fields on the left. Here, the designer develops the ability to conceptualise and shape products like brand identities, interior spaces, buildings, consumer goods, etc.
The emerging design practices, on the right, focus on social needs or people's needs and aspirations. They demand a different strategy because they must take a more extended view and adopt broader perspectives.

Sanders & Stappers (2012) also mention that in response to the shifting foundations in the design research landscape, the design development process has also been changing, creating a very large front end of the design process that has grown and gained more importance. This front end is mainly referred to as the 'fuzzy front end' because of its explorative and chaotic nature. The goal in this part of the process is to figure out what the most important and relevant problems are that need solving. There is no clear pathway, and it is often in this phase still unclear what the deliverable of the design process should be. What could be, what should be, and what should not be designed is decided in this phase.



Design is not about visualisation and individual creativity anymore. Designers are invited to identify and solve problems that cannot be addressed by individuals alone. These problems are referred to as so-called "wicked problems". Wicked problems can be described as problems that are: " difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize.

Moreover, because of the complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems" (adapted from Sanders & Stappers 2012, Rittel and Webber, 1973). De Bont (2021) in his article "Furthering Victor Papanek's Legacy: A Personal Perspective" argues the need for a paradigm shift in design research, borrowing Papanek's idea of a holistic view that can help designers address the complex problems of our times.

The answer to addressing wicked problems is through collective creativity. Sanders & Stappers (2012) argue that the real experts, when discussing designing and innovating future experiences, are the people we are attempting to serve through the design process. In the case of this thesis, the cabin crew at KLM. This shift in mindset allows future users to step into the design process at the (fuzzy) front end of the design process and allow designers to design with these users, instead of for them. To do this, the playing field needs to be set up in a way that supports a shared language by providing tools for the participants of the process to express their creativity and support the exploration of new ideas.

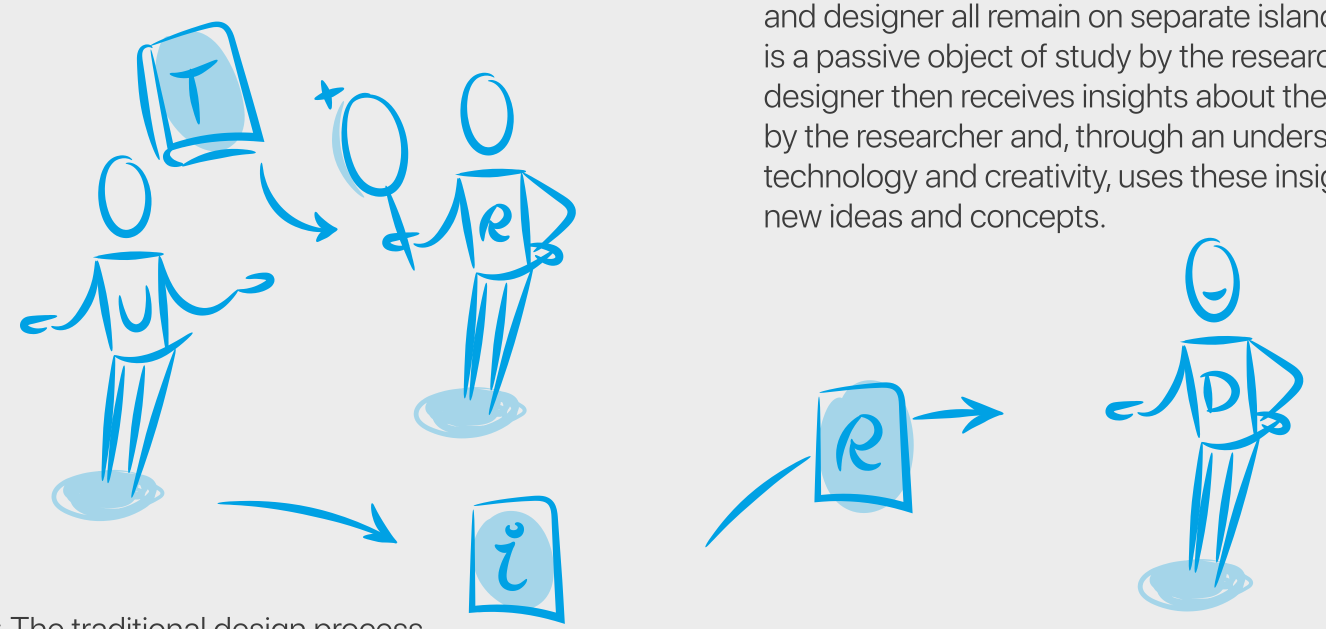


Fig. 14: The traditional design process

This ties into how the design landscape shifts from user-centred design to co-designing. In a (caricature) of the classic user-centred design process, the user, researcher and designer all remain on separate islands. Here the user is a passive object of study by the researcher. The designer then receives insights about the user gathered by the researcher and, through an understanding of technology and creativity, uses these insights to generate new ideas and concepts.

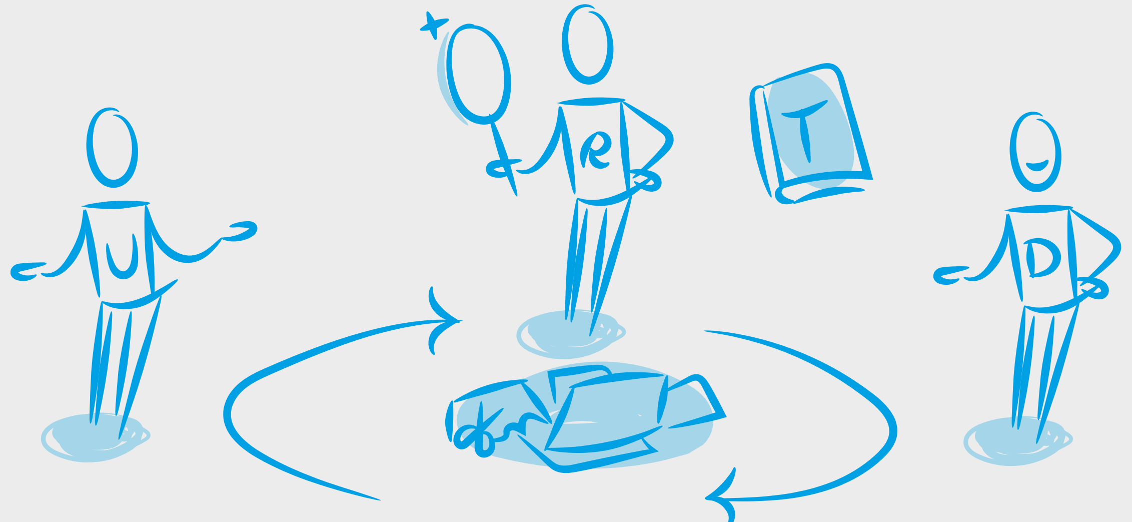


Fig. 15: A co-creative design process

In co-design, the three main characters are mixed up. The user who will eventually be served through the deliverable of the design process is seen as a valuable player in the co-design process. In this process, the user, researcher and designer all work together and on more or less the same level to move towards the best-intended outcome of the design process. The user is granted the role of the 'expert of their own experience' (Sleeswijk Visser et al., 2005) aiding in synthesising idea generation, knowledge and concept development. According to Ehn (1992) co-designing from a participatory point of view focuses on learning. Users and designers in a co-designing process learn from each other by sharing their unique knowledge and experiences. To do this, tools for ideation are deemed necessary to facilitate the co-design process and evoke the participants' creativity. Because design skills are essential in creating these tools, the designer and researcher (who in the case of this thesis are the same person) must collaborate.

3.2 The case for XR and co-creation

To create a successful tool for fostering creativity in a co-design process, it is vital to know the level of creativity that will be operated on. According to Sanders & Stappers (2013), there are four levels of creativity namely: doing, adapting, making and creating. Hence, "it is important to offer relevant experiences to facilitate people's expressions of creativity at all levels. It takes different kinds of support at the different levels of creativity" (Sanders & Stappers, 2013). They also state it is best to:

- Lead people who are on the "doing" level of creativity
- Guide those who are at the "adapting" level
- Provide scaffolds that support and serve peoples' need for creative expression at the "making" level
- Offer a clean slate for those capable of creating things from scratch.

In people's daily lives, people can live on all four dimensions of this creativity. Sanders & Stappers (2012) mention that people can for instance be on the creating level when it comes to cooking, but on the adapting level when it comes to using technology. According to them, people with a high level of passion and knowledge can become co-designers. This is for instance already happening in healthcare where professionals from the sector are collaboratively working in design to define new healthcare environments and systems (Sanders, 2006). Based on this fact, the author makes the case that other domains of collaboratively working (outside of healthcare) could also yield beneficial results. In this case, we will investigate the role of flight attendants collaboratively designing their future workplace in the Flying-V.

In the last decades, not only the field of design but the subcategory of product design itself has experienced substantial changes due to technological innovations (Schneider, 2021). From hand-drawn orthographic views to the implementation of computer-aided design (CAD) to software moving from the mainframe to personal computers. Real-time collaboration and advancements in computer graphics have all aided the further development of the product design process.

"The next paradigm shift in the field of design is likely to be powered by Extended Reality (XR)" (Schneider, 2021) The idea of wearing an HMD is not new. The first AR/VR headset was already drafted in 1968 by Ivan Sutherland (Sutherland, 1968) and VR experienced its first boom in the late 1990s (Schneider, 2021). Historically, VR has been limited regarding resolution and movement synchronisation (Slater, 2000). However, companies like Meta, Microsoft and even more recently Apple have created new momentum for the technology. These tech companies have aided in XR technology becoming more affordable and easy to use in commercial and consumer settings. By becoming more readily available XR is now used in everyday life, most notably in the entertainment industry. But engineering, architecture, healthcare and education are also making use of XR (Quint et al., 2015; Bellini et al., 2016)

Opening up the possibilities for design students and professional designers to, for instance now, prototype and design and co-design with users and colleagues (Söderlund & Evans, 2022). TU Delft has also adapted to this by founding a dedicated XR-zone in the campus library.

The growth in XR technology is already influencing the design world where benefits look to be promising. XR sketching offers a whole new way of immersive conceptual design and collaboration and visualisation (Gravity Sketch, 2020). Bridging the gap between 2D and 3D ideation. Designers have a large array of skills under their toolbelt and XR with its ability to streamline processes and allow designers to create even more immersive experiences seems to be added to that arsenal in the future. The faculty of Industrial Design Engineering now also offers a course teaching XR sketching with Gravity Sketch.
Schneider (2021) argues that whether working in AR, VR or MR, the biggest draw of this technology is the promise of immersive collaboration. He states that interdisciplinary teams can benefit from XR platforms to evaluate designs and accelerate decision-making jointly and adds that being able to experience virtual settings can reduce uncertainties while facilitating (a)synchronous communication in a remote or on-site setting. "XR offers the potential of co-creation with experiences that have never been achieved at this level before" (El-Jarn & Southern, 2020). Furthermore El-Jarn & Southern (2020) state that they have found XR tools improve the chaotic fuzzy-front end of the design process and therefore have a wide range of benefits, such as more efficient designers, designers being more collaborative and more time and potential cost savings.According to Söderlund & Evans (2022) recent research does not pay much attention to co-design in XR in immersive collaborative virtual environments. This is also observed by El-Jarn & Southern (2020) they state that whilst reviewing the current work in this field, they found there was "a notable lack of empirical studies from the past five years on using modern VR equipment, software and the exploration required with those design tools."

Fig 16: A rendering of people collaboratively working on a model, courtesy of Gravity Sketch

3.3 Traditional co-creation and XR

As stated before there is a lack of empirical studies in design from the last five years on using modern XR (VR) equipment (El-Jarn, 2020). Furthermore, to the author's knowledge, the research in combining traditional co-design methods, such as using generative design (which will be explained in the next section) in combination with collaboration in XR is still largely unexplored.

As mentioned in the book Convivial Toolbox generative design empowers everyday people to promote and generate alternatives for current situations. In the case of this thesis, the people we refer to are flight attendants from KLM. However, in the pilot workshop hosted as a testbed, these people were fellow designers and engineering colleagues who took the role of flight attendants. "Generative Tools" refers to the creation of a shared design language. The stakeholders use this language in the collaborative process where designers, researchers and other stakeholders use this to communicate visually and directly with each other. The design language is generative in the sense that it allows users to express an endless number of ideas using just a small number of stimulus elements. Thus, the generative tools approach is a method for exploring the ideas, dreams, and insights of those who will be serviced by design. This is demonstrated in the book 'Service Design for Industrial Designers (Sleeswijk Visser, 2013), where part of the inspiration for this thesis comes from. In a design case example, doctors and nurses were invited to design their ideal operating theatre using generative design tools. Generative design aims to promote and inspire alternatives to the current situation (Sanders & Stappers, 2012).

Fig 17: Co-creating a nursing room, adapted from Sanders (2006)

In a pilot workshop described in the next chapter, the author investigates how traditional means (non-XR) of generative design can be combined with XR technology. Sanders & Stappers (2012) describe generative design research as providing people with "a language with which they can imagine and express their ideas and dreams for future experiences". They go along to say that these ideas and dreams in turn can inspire other stakeholders in the design/development process.

For the pilot workshop, the author has taken an educated guess as to where to insert XR into the process. Sanders (2006) mentions how toolkits can be of great benefit for envisioning future scenarios and environments. She uses the term 'make tools' to refer to objects that participants can use in the co-creative process. Hence, a wide range of these co-creative 'make tools' have been supplied, such as 2D and 3D objects. Inviting users to say, do or make things, as mentioned by Sanders & Stappers (2012). Chapter 4 will explain the author's approach to the pilot workshop.

3.4 Hypotheses and assumptions

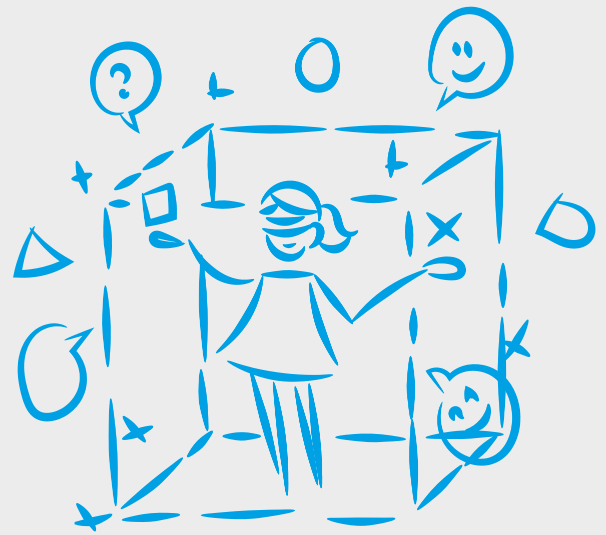
Because a growing body of evidence suggests that XR can be of benefit in the design process, this thesis will focus on how XR specifically can be of more benefit to the field of co-creation within the design process. Together with generative tools, it is assumed that the synergy of both mediums can enhance one another.

Hypothesis:

"The integration of Extended Reality (XR) and physical 'make tool' objects in the co-creation process can enhance the efficiency and effectiveness of the design process in the context of creating a galley design for the Flying-V." (Such as presented in Sleeswijk Visser (2013))

Assumptions:

1. Generative design 'make tools' will work best within this co-creation session because of the nature of the design brief.
2. Designers and other stakeholders involved in the co-creation process have little understanding of XR but a willingness to engage with XR technologies.
3. Participants can effectively combine physical objects with XR technologies to produce a seamless co-creation experience.



Research Questions:

1. How can the integration of physical objects and Extended Reality (XR) enhance the co-creation process in the design of the Flying-V interior?
2. What benefits and limitations are associated with using physical objects and XR in a co-creative design process?
3. How does using XR and "make tools" in co-creative design affect the final design outcomes?

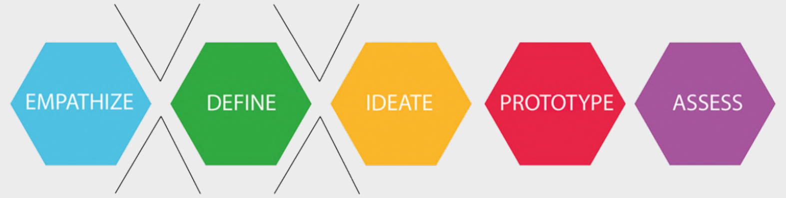
3.5 Design process gap

Current research seems to miss thoroughly exploring how Extended Reality (XR) technology, traditional co-creation tools, and co-creation methods converge. While each of these elements has been studied separately, their combined impact and potential benefits have not been fully explored.

Initiatives of examples utilising XR, specifically in the aviation sector, include aircraft mock-ups in VR (XR), which are realised based on preliminary aircraft design data (Walther et al.,2022). In this case, the application of XR was deployed as a visualisation tool, translating cabin data into a viewable design. A similar example to this which is still in development, is from Fuchs (2021), where aircraft design data is fed into a system that generates an automated layout of the cabin, which can then be evaluated in XR.

Another example of using XR in aviation has been used for evaluating cabin interiors of business jet aircraft (De Crescenzio, 2019). Likewise, Airbus has multiple XR-related technologies for evaluating and experiencing cabin interiors. The author experienced these during a visit to Airbus in December 2022. Another article partially relating to this thesis is by Joo et al. (in press.) This paper describes how XR and different types of users contribute to the evaluation of aircraft interior design of the Flying-V in a co-creation setting. As a general theme, the main focus seems to be on evaluation instead of (co)creating designs from scratch.

A paper by DLR on investigating VR technology in the aircraft cabin design process (Moerland-Masic, 2021) is a first step in shifting from evaluating with VR (XR) to designing in XR. This paper comes closest to what is being researched in this thesis. The paper describes combining design thinking principles with XR, hence involving the end-users in the design process.



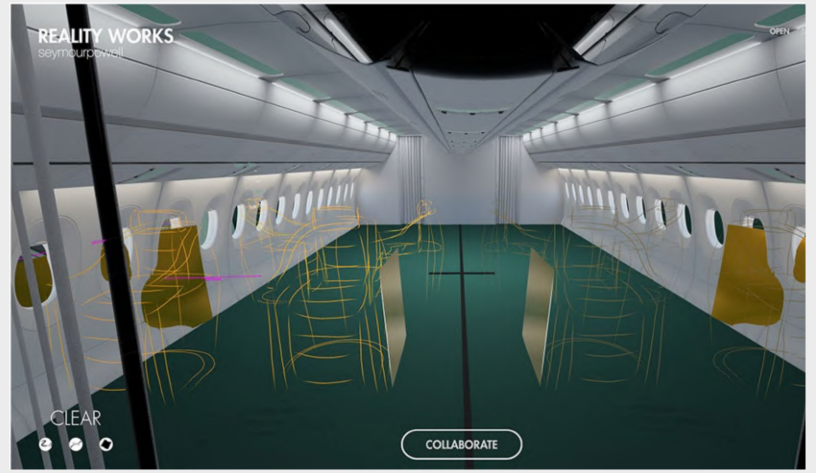


Fig 18: VR model of a business class, quick sketch (designer: F. Reimer)

Since co-creation and co-creation tools are still largely unexplored in combination with XR (especially traditional co-creation tools), this presents a unique opportunity for research that not only brings together these elements but also contributes to a deeper understanding of how such integration could benefit the fuzzy-front end of the design process. While various methods of using XR exist, this thesis will focus on experimenting with a novel combination of using 3D 'make tools' and XR in the co-creation process to develop a method for DLR for future co-creation sessions.

Before checking the hypothesis, a pilot is done to see how XR can play a potential role in the co-creation process. In addition, the most suitable phase in the design process is studied.

Fig 18: The author of this thesis and a KLM flight attendant immersed in XR

Design Process

4

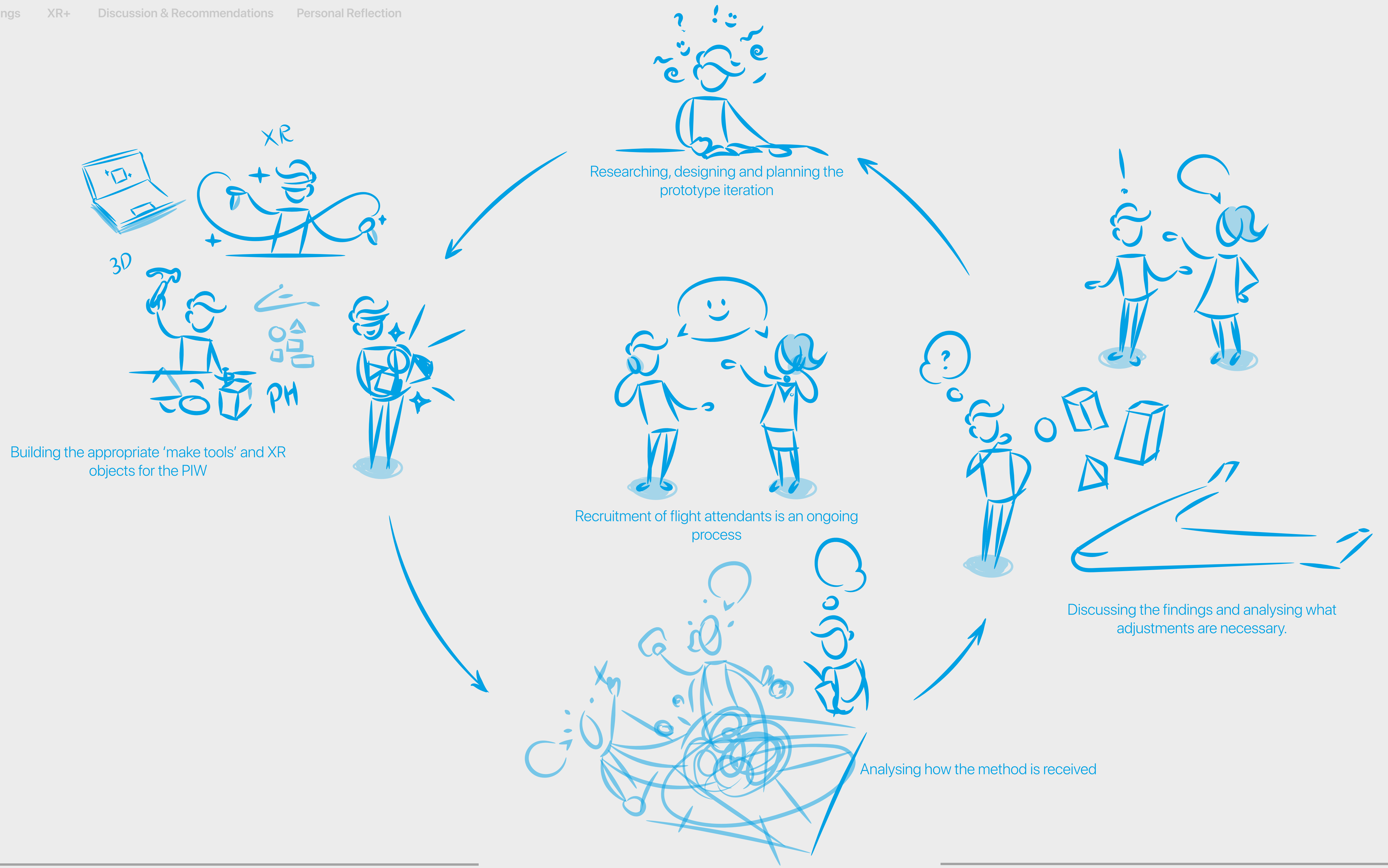
4.1 Overview Methodological Approach

The core of this research revolves around exploring how Extended Reality (XR) can synergise with co-creation within the context of an aircraft galley design for the Flying-V. Because no method is set in stone for doing this, this chapter outlines the author's approach to synthesising methods. This chapter explains the discovery-oriented, trial and error design process(es) for approaching this task. A co-creation workshop combined with XR has been set up as an initial pilot. It is worth noting that the design process in this research is iterative, allowing outcomes from one session to inform and refine the next.

Initial Concept

The first pilot workshop was based on an educated guess by the author based on literature research from but not limited to Astles (2022), Moerland-Masic (2021), Sanders (2006) and Sleeswijk Visser (2013) and used as an initial pilot for creating further workshops. This served as a starting point for more workshops to evolve. These workshops will be revered to as Prototype Iteration Workshops or PIWs. The following chapter will detail this first pilot workshop, and the outcomes of this workshop will inform the following PIWs.

The way of working is iterative, fast-paced and trial and error based. Literature research informed the initial set-up of the pilot workshop. Findings from the workshop were used to adjust the next workshop with actual cabin crew members of KLM. These workshops are explorations of the final method DLR could potentially use and hence are iterations of the final prototype being made.



The design process of the author starts with a researching, designing and planning stage. In this stage the design of the workshop is laid out based on literature and educated guesses of the author. Factors such as what stages will be included? How much time will each part take? Etc. are considered. A plan for which materials such as physical objects and XR objects is also drafted.

The next stage is all about designing the workshop materials. This can range from building models in CAD and 3D printing them, preparing XR objects in the virtual world to editing videos to show during the session.

The next stage analyses how the method is received and takes place during the session. Here insights are recorded and noted.

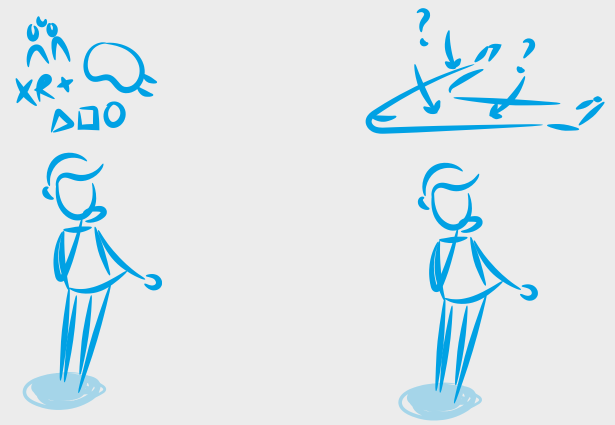
After this findings and results of the workshop are discussed. An analysis of what needs to be adjusted is made.

The results are fed back into the planning and designing stage ready for a next iteration loop.

It is worth noting that the recruitment of participants, in this case flight attendants was an ongoing process. Hence they are placed in the middle of the loop.

4.2 Co-Creation Pilot Workshop

The rest of this chapter describes the process of testing out a particular pilot set-up to see what does and does not work when combining XR with the co-creation process. It is important to note that there is no 'one' co-creation process, meaning that every design project where co-creation is required or applied can follow a different set of rules or instructions. There is no one-size-fits-all when it comes to co-creation, just like traditional design processes do not follow a strict set of rules.



In this thesis, two layers of design are taking place. The first layer refers to the concrete design of the Flying-V's galley: the subject of investigation and analysis within the co-creation session. This level engages the cabin crew in collaborative ideation, relying on their expertise, preferences, and aspirations to create an optimal galley within the constraints of the Flying-V. The challenge here is not only to come up with creative solutions but also to foster a collaborative atmosphere among the crew members.

However, the focus of this thesis leans more towards facilitating this collaborative effort, marking the second layer of design. This stage involves shaping a process that incorporates XR technology to enhance co-creation. In other words, the task is to design a part of the design process itself or create a method/tool that supplements the design process. The primary question here is: What constitutes the ideal co-creation process when integrating XR into the design process?

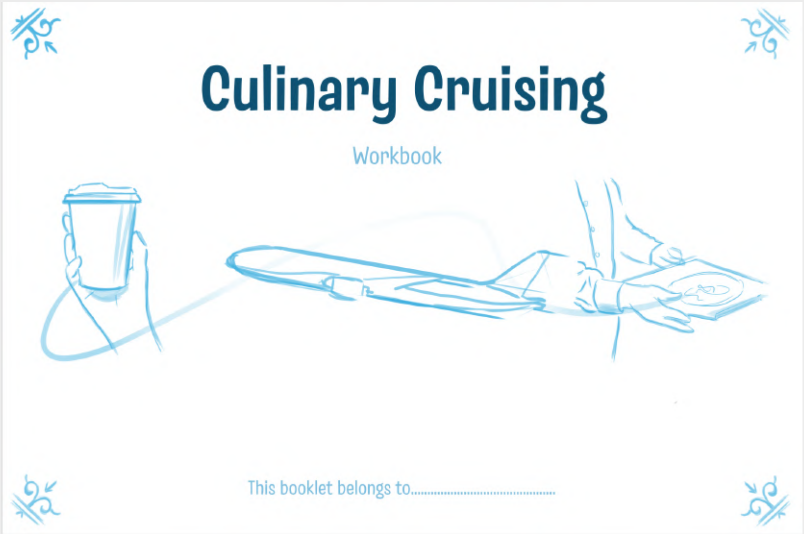
Introduction to initial ideation and exploration
Objectives for this phase of the project

The aim of this first pilot test is to see how XR can play a potential role in the co-creation process. In this context, 'ideation and exploration' refers to identifying the optimal placement of XR within this process. This is initially done based on an educated guess from the author, supported by literature. As previously suggested, XR could be of benefit in the validation phases of the design process (De Crescenzio, 2019). The author, in this case, makes an estimate on where to insert XR. There is however also much research indicating that utilising XR in the early stages of the design process is beneficial for non-designers (Astles,2022); hence users could benefit from XR when exploring new concepts since this co-creation can take part in the fuzzy front end of the bigger, overarching design process. Discovering ways in which users could benefit from XR is an objective of the first session. These first discoveries, positive and negative, can serve as a baseline and tool to measure success in later sessions. It is important to note that XR serves as an umbrella term. While the particular pilot session focuses on VR, references to VR will be referred to as XR.

Pilot co-creation session with designers and engineers
Preparation for the session

This first session is a baseline and initial starting point for future co-creation sessions with flight attendants. Before setting up the pilot session five people from varying backgrounds were recruited to join the session. They were only told they would be engaging in a co-creation session. When further details were requested, they were told that they would design part of the interior of the Flying-V. Information was kept at a minimum to keep biases as low as possible. There was no mention of galley design or using XR in the workshop. A total of three designers and two aerospace engineers signed up for the session.

Since one of the aims of this project was to involve flight attendants in the co-creation process, there was a need for the participants to think like a flight attendant. By agreeing to join the workshop, they were handed out a 'sensitising booklet' (van der Burg, 2010). The booklet is a printed bundle of exercises that primes participants to think about certain themes before entering the session. There are a few exercises that have to be completed over a number of days. Every day corresponds to a new page in the booklet. After some discussion with one of the author's supervisors, the booklet was abbreviated from a workbook of 4 days to a 2-day booklet. The goal was to support the participants in stepping into the shoes of a flight attendant and thinking from their perspective. Some specific questions about the flight attendants were also asked in the booklet.



The goal of the sensitiser was not explicitly mentioned in the booklet. The booklet was divided into two parts: "Inflight meals/being a passenger" and "Serving food in a different setting". It was hypothesised that these themes would lead the participants' minds to be more attuned to the role of a flight attendant when entering the session.

Following the sensitisation, the five participants were asked to use materials such as foam, cardboard, Lego, paper & other materials to get creative supplied by the facilitator (author). A large sheet of paper, made up of multiple A3-sized segments and featuring a 1:20 scale top view of the Flying-V, was made available for reference.

Schematic diagrams of seating layouts complemented it. To guide the participants at the beginning of the exercise, a concise design brief was provided. Unfortunately, one participant had to cancel due to illness. The other four remained. An overview of the session is described on the next page, picture by picture. It is written in an instructional style.

Fig 19 & 20: The author creating the first draft of the Flying-V floor plan for co-creation.

4.3 The Co-Creation Steps

During the briefing of the participants, the facilitator explains that the workshop is split into three equal parts, with a 15-20 minute break between each part. The first part is all about immersing oneself in the context and getting familiar with the topic. The second part is about designing the 'new context' in this case, one or more galleys of the Flying-V. Lastly, the third and final part is about immersing oneself in the newly created context in XR followed by a discussion on the experiences participants had of this.

Immerse in the context

Design the new galley/ context

Immerse in XR (VR)

Before the workshop: Participants are handed out a booklet and asked to fill in the sensitising booklet before coming to the workshop.

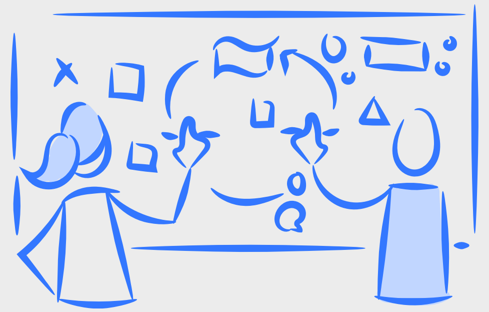
Introduction and welcome. The facilitator ensures everyone is seated correctly and supplied with a drink or a snack.

After briefing the participants about the structure, the facilitator explains the goal of today. "Welcome, one and all. You are either designers or engineers, and you have had to think about food being served in your personal or private life. You are all experts in your own personal experience, and this is why I wanted you to have thought about this. Since you are also experts in engineering or design, I today want to combine your two expertises in this session. Hence the fact why I have brought you here." Make them understand why they are joining this session.

Participants are told they will create something together today and that all input is appreciated."You are the designer and the user of the specific product today". In this session, it is also explained that the participants are welcome to share any experiences that come to mind and that they should not hesitate to ask, shout or share things they want to at any time in the session.

The participants are asked to present one or two pages from their sensitising booklet to the group. They have time to share their experiences based on the sensitising booklet with all of the other participants. As the facilitator, ask them why they particularly wanted to present this page/these pages.

Discuss what we have just written out on the boards. See if there is any overlap or if you, as a facilitator, can make clusters that people already find important. Give them stickers that indicate whether or not this is important for them.



The participants are asked to get their thoughts on the whiteboards. "What do you think of when you think of these things?" The facilitator writes all the ideas down and makes an overview on the whiteboard to fall back on.

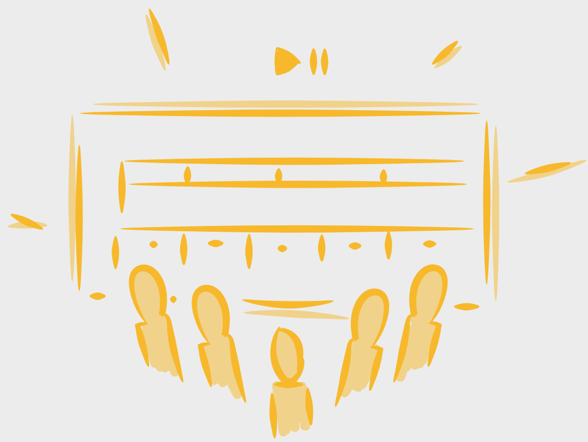
"You have just shared all these thoughts and ideas. I've got some visuals from an existing flight: KL641. This is an example case you could design for. You will devise a scenario for the ideal galley situation in the future on a similar flight. You will now watch a video as inspiration"

Break Time!

Immerse in the context

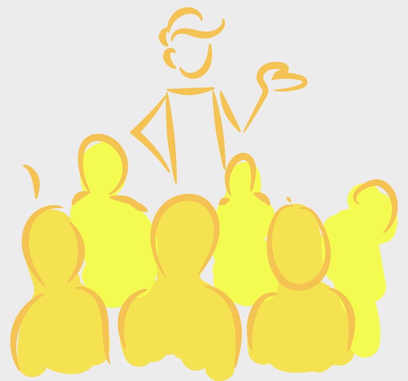
Design the new galley/ context

Immerse in XR (VR)

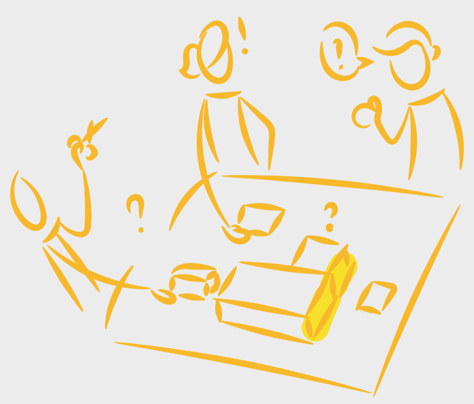


Introduction to the brainstorming. The participants are shown a video to trigger inspiration on current galleys. Developments in the field of VR/XR technology are presented to probe and inspire participants and are aimed to trigger their imagination.

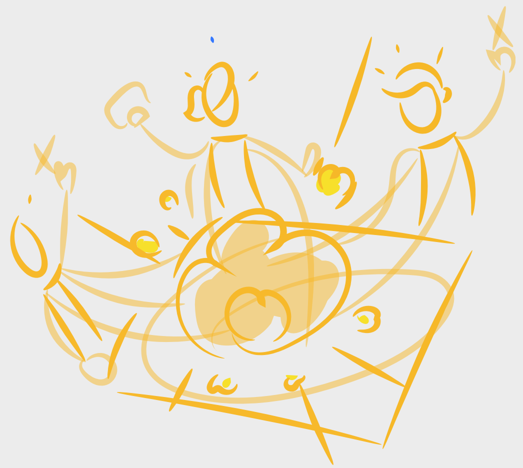
"Design the ideal galley for in 10 years into the future. Next to designing the galley please also come up with how it will be used. So a scenario, so that the product does not exist on its own. So, for instance how an FA would use this newly 3D-created galley. Someone walks in/walks out etc."



You will now be tasked with creating the ideal kitchen (galley) for the Flying-V flying from AMS-JFK. The video can be used as guidance for the requirements. Additional requirements are listed in a small design brief.



Using different materials such as cardboard, foam, wood, plastics etc, participants are invited to make their own version of the ideal galley and to play around with them like Lego. Legos are provided too! Participants would ideally be coupled in pairs to stimulate interaction and cooperation. This was, however not possible due to a cancellation of another participant. In the end, one group of 3 participants teamed up. This exercise uses physical objects.



Group members will present their 3d designs to the rest of the group and explain why they made particular choices. As a facilitator, remind yourself to ask open-ended questions about why they made particular choices and how they came to these conclusions. What underlying values motivate these choices?

Fig 21: The pilot workshop hosted with employees of DLR, creating hands-on with physical objects.

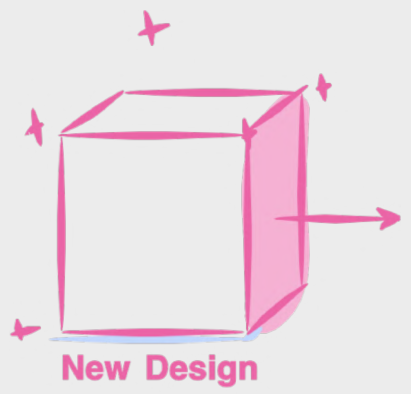
Break Time!

Immerse in the context

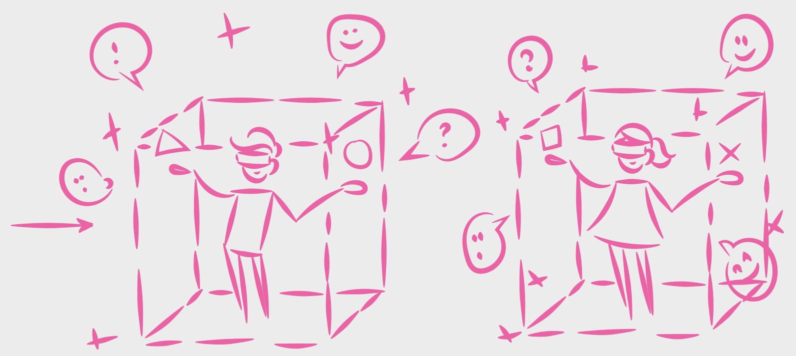
Design the new galley/ context

Immerse in XR (VR)

Introduction to the brainstorming. The participants are shown a video to trigger inspiration on current galleys. Developments in the field of VR/XR technology are presented to probe and inspire participants and are aimed to trigger their imagination.

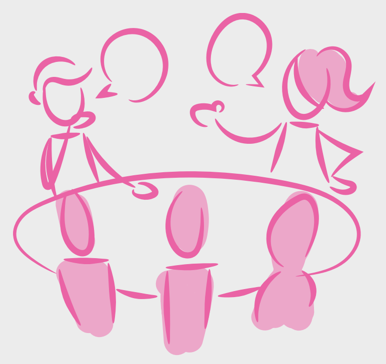


During the break, the facilitator quickly mocked up the design of the galley made by the participants in the previous section. The participants are invited to immerse themselves in their newly created design.



Participants are asked to immerse themselves into the role of a flight attendant. This is encouraged by transporting them into a XR world. In an ideal setting, all participants would be able to access the XR world simultaneously by all wearing a headset and discussing their findings on a 1:1 scale and making adjustments with the designer also immersed in the virtual world. Ideally, using multiple headsets.

While talking out loud, participants are invited to share their immersion experiences in the virtual world. The experiment showed that participants also imagined themselves as passengers, not only flight attendants.



Participants are invited to share their experiences of where the VR was used in this case. Did it make sense to use VR in these places in the process? Why (not)? Where would they have liked to have more visual feedback? Where would they like to share more info on the design on a 1:1 scale? Did VR make it easier/harder? Did it make sense at all?

Fig 22: Scenes of immersion in XR and discussion after the session

As mentioned in the previous steps, the 3rd half of the pilot workshop was reserved for the immersion in XR and the group discussion. From the discussion and immersion, insights emerged that could potentially benefit the next co-creation session.

XR as a tool for co-creation

"Where does XR make the most sense in the co-creation process?" Making sense implies that XR would be a logical extension to the co-creation process or of benefit to the co-creation process. If we look back at the benefits of XR, as mentioned in Chapter 3, we could assign these values to certain process steps in the co-creation process and then judge how applicable XR is in this particular process step. However, before attempting to do this in the next workshop, we should consider the feedback from the participants of the pilot co-creation workshop.

Findings and Feedback workshop

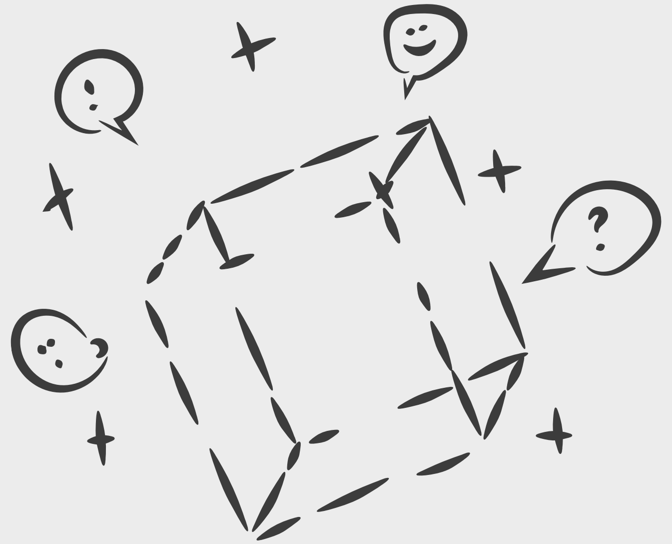
"Where does XR make the most sense in the co-creation process?" Making sense implies that XR would be a logical extension to the co-creation process or of benefit to the co-creation process. If we look back at the benefits of XR, as mentioned in Chapter 3, we could assign these values to certain process steps in the co-creation process and then judge how applicable XR is in this particular process step. However, before attempting to do this in the next workshop, we should consider the feedback from the participants of the pilot co-creation workshop.

In summary XR seemed to have both positive and mixed impact on the participants, namely:

- Enhanced spatial understanding
- Stimulated creative thinking
- Facilitated collaboration.

However there were also concerns and limitations discussed:

- Overwhelming possibilities
- Need for context and constraints
- Learning curve



Enhanced spatial understanding

XR can potentially enhance participants' understanding of space, scale, and spatial relationships of objects to each other. It allows them to visualise and evaluate their designs in a more immersive and realistic manner, which can lead to more informed decisions regarding new concepts and designs. XR can represent spaces for a user by providing virtual spatial information and creating the illusion of depth and immersion, hence contributing to the understanding [of the virtual world] by the participant (Kalisperis, 2006)

Feedback participants:

"And it's good to have the first impression, like on a paper, to know the setting, to know, okay, we have two fuselages combined wings, and to get your mind ready,and then switch."

"I think we have more the real expression...We have more feeling for it. Because when we put it there...And then when we saw it, it was like, Oh, this wall seems really different now."

"You could more imagine that there is a wall and an ending.So this is the next level,so you really see the boundaries and it's also for me that the space here is not as I imagined it on the [2D paper] layout."

"Is it different than using a floor plan? Or what is the difference? I have more feeling for it. Like for like the expressions in the room and the heights and the shapes."

Interpretation of statements:

These quotes suggest that XR allows participants to experience designs in a more immersive and realistic way than traditional 2D design tools. By being able to walk around and explore the 3D space, participants were able to understand better how the different elements of the design fit together and how they would feel in real life. Also, the ability to switch between different modes of representation, such as the sketches made on the floor plan on paper and the XR experience, could help participants create a more complete mental model of the design.

Stimulated creative thinking

Using XR in the design process can stimulate creative thinking by allowing participants to explore new possibilities and ideas in a virtual environment. This can lead to innovative design solutions that may not have been considered using traditional methods. According to Thornhill-Miller et al.[4], XR can be used in five different ways to enhance creativity. One of them is the facilitation of the creative problem-solving process. The quotes beneath illustrate what XR did to the participants in this domain.

Feedback participants:

"It looks quite inviting and comfortable to have a bar area. You could use it from two sides, maybe this one thing could be enough as a module. At least I would have different other ideas seeing that now like this"

"Yeah, so also, this space seems not to be quite much. Could be also another, one of those sections, tiny multifunction rooms. But could you imagine if you're standing here and relax, and also one of the people standing here, and here is all the trouble, and then they are all just swarming around to serve the people who could be disturbing."

"I like the shape of the bar. Because I think we just drew it as a square, and this is nice because it's a more inviting body because of the U-shape"

"It could be like a bar type situation. So it's service, but you still sit here. These type of restaurants, they prepare it and put it there and you just pick it up. You pick it up and the kitchen prepares it. And then they call you from the seat. Seat number 24, please pick up your food over there. Cool."

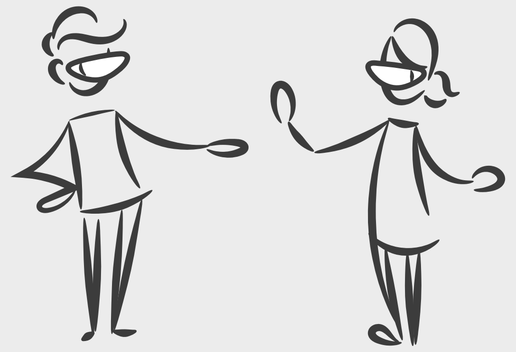
"Yeah, I didn't see that as a bar earlier, but now having it here, it looks like an idea".

"Yeah, so also this space seems actually quite large. Could be also another of these wonderful sections and tiny multifunction rooms."

Interpretation of statements:

Working in XR led participants to understand the design more fully. The ability to move objects and make changes in real time could, in future sessions, allow for quick iteration and experimentation. This could, in turn, encourage participants to try out new ideas and explore different design possibilities. It could be hypothesised that the immersive aspect of XR, as opposed to the 2D tools, could help participants feel more connected to the design process and more invested in finding creative solutions.

Working together in a shared virtual space could encourage participants to collaborate and hopefully build off each other's ideas, which could lead to different creative solutions which may not have arisen using non-XR tools.



Facilitated collaboration

XR can facilitate collaboration among participants by providing a shared virtual environment to discuss, iterate, and evaluate design concepts together. This could create a more inclusive and collaborative design process, ensuring that various perspectives are considered. As stated by Yu et al. [5]: "There is currently a lack of critical understanding about the effectiveness of these virtual technologies and various emerging add-on tools for meeting the needs of design collaboration, especially at the early design stage".

Feedback participants:

"I would personally be in a collaborative environment in VR. Because looking from the outside world and the projection of the VR is a different thing than looking inside of it."

"So I think if you build it in VR, the others should also be in VR seeing it." "If it's a collaborative environment where everyone's in VR, that sounds more efficient.I think you will be more into it when you also see it."

"Whether they need to also be able to move [objects] at the same time might be a different question, because that's collaborative. But everyone's moving stuff at the end. Someone needs to know, okay, go start a new thing."

"When you're talking about the 3d design, I'm putting it here, how about we put it here? Then you can show it.It's a collaborative environment where everyone is in the game, that sounds more efficient. I think you will be more into it when you also see it. When you see it, you've got more like the tingling in your fingers to be like, oh I want to move it to the end."

Interpretation of statements:

These quotes suggest that XR could be a platform for collaboration between participants. Although unsure of how exactly this would work, it was agreed that all being immersed in XR simultaneously would be most beneficial. However, there were also some concerns and limitations discussed. These are listed in the next three sections.

Overwhelming possibilities

The infinite possibilities and freedom XR provides can sometimes overwhelm participants, making it difficult for them to focus on specific design objectives. This can result in a lack of direction or a sense of being lost in the virtual environment.

Feedback participants:

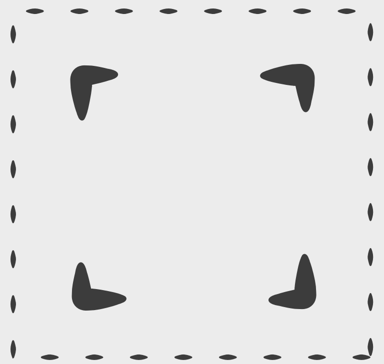
Talking about the flight attendants: "because I think that they have never been in a situation to engineer, design, or create something.So I guess there's a big boundary because in their work they have like structured plans, everything's every hour is structured and standing there in a new, I mean, full new aircraft and they don't know what is where, in which direction they have to cater, what's the plan."

"Because I think for us, it's a playground. And say, we can do everything, but they- For them, it's like, hell."
"If you put them in a space they are accustomed to, they will give you better results."

"I think maybe a really typical situation, OK, now you have this flight, you have those conditions, you have x passengers, this is the section, more introduction, more schedule would be helpful to implement their work behaviour to this new situation."

Interpretation of statements:

These quotes suggest that there may be some challenges associated with using XR for design. It is hypothesised that a need for clear goals and constraints is needed to avoid feeling overwhelmed by the possibilities XR can provide, but also for guidance and a clear and efficient way of working.



Need for context and constraints

Participants expressed the need for more context and constraints within the XR environment. This closely ties into circumventing the possibility of being overwhelmed. Floor plans and other spatial layouts could aid in providing a clear boundary in the virtual world. This would help them better understand the design space and make more informed decisions. Without these elements, XR might not fully unleash their imaginative potential

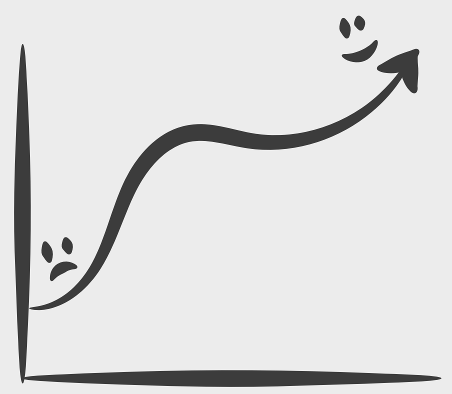
Feedback participants:

When referring to the floorplan and pictures of the Flying-V: "Maybe you could just put these, what you put on the floor, just put this picture in Gravity Sketch on the floor. Yeah."

Talking about immersing oneself in the VR world:
"...maybe have these boundaries and this setting in VR to know or to realise the distances and all the stuff."
"...I miss that in VR, so. Yeah a little more boundaries"

Interpretation of statements:

Having some context or constraints can help ground participants in the design problem and give them a sense of direction. This is where the focus on the galley could come in beneficial. This can help guide the design process and prevent participants from getting too far off track.



Learning curve and adaptation

Some participants might be more accustomed to traditional design methods and may need time to adapt to using XR as a design tool. This could hinder them to realise their full potential in a co-creation session. The engineers and designers in this pilot test said they would feel comfortable using XR quite quickly but also expressed this might not be the same for everyone. Two of the designers also already had experience using XR. Taking about using XR on their own from an engineer's perspective and how fast they could learn it:

Feedback participants:

"It depends on the fidelity. It depends on the person. I would say I can adapt to that really fast. So really it depends on who is participating. So yeah, I would say I would be comfortable after a few minutes to move blocks and all this stuff."

Talking about looking at XR on a screen vs. being immersed:
"Even for me walking [in] it, from walking in the VR to walking through it, there's a different experience level there."

Discussing solutions for circumventing the learning curve:
"So maybe just one person who's a pro in this software, and then maybe to ask, how can I arrange it? Or can you maybe scale it? And then one person for you is also doing stuff."

Interpretation of statements:

Like any new tool or technology, there may be a learning curve associated with using XR for design. Participants may need time to get used to the controls and interface, as well as learn how to navigate if this is applicable. An experienced facilitator could potentially lower this hurdle, or a 'foolproof' design might also have potential. In the best-case scenario, participants might even work more efficiently in XR than in traditional methods.

Fig 23: The author in the room where the first pilot session took place. On the right three tripods can be observed, two of which contained sensors for the HMD to work. The HMD requires a computer and cable to work.

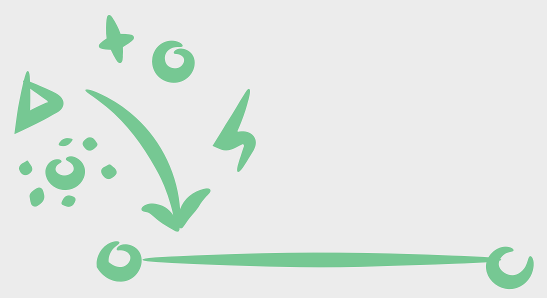
4.4 Identifying Key Concepts & Themes

Directions emerging from the pilot session

Based on the previous workshop, we can start to think of where XR potentially makes the most sense. But not only where it makes the most sense but also how? And, moreover, specifically tailored to the design/innovation processes currently present at DLR. There are a few main themes that stand out for the potential usage of XR

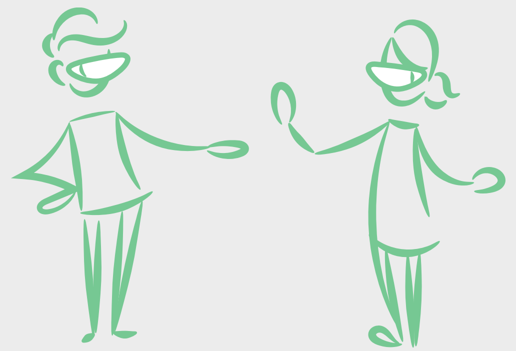
Encourage early experimentation

According to Astles (2022) XR tools and techniques can benefit the early stages of the design process. The question is still if this also applies to the co-creation workflow.
We could hypothesise that this would also be the case for the co-creation process since the difference is a collaborative versus a non-collaborative effort. In this case, XR could encourage early experimentation that can help iterate more human-centred design concepts during the brainstorming phase of the design workflow because of the 1:1 scale and immersive nature of the tool.
One participant added: "To me, the first part, everything we had until the first break. It was mainly like not designing per se, but like getting feedback, like I said, and surveying, etcetera. And everything beyond that is design." This quote reflects that after sensitising the real 'designing' began according to this participant. For him it made sense to introduce XR when 'designing began'. This can be seen as an example of an early step in the design process but a later step in the co-creation process since sensitising is arguably already part of the co-creation process.



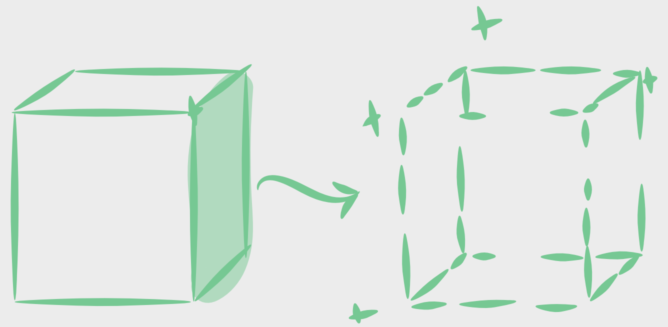
Facilitate collaboration

To maximise the benefits of XR, we can consider using it as a tool for collaboration among participants. This can be done whilst exploring early concepts or experimenting in the early phases of the process. There are multiple ways in which this can be achieved. For instance, by all entering the same virtual room in a Gravity Sketch session either remotely or in person. Or by having one facilitator guiding the participants through a virtual world while they give him instructions and feedback. Both options can help create a dynamic and engaging design process. El-Jarn et al. (2020) mention that "this collaborative immersive experience has the potential to far outweigh other CAD methods of co-creating, designing and iterating in the early stage of the design process."



Combine 2D and XR

As stated in the workshop, a combination of 'traditional' 2D elements in combination with XR could help participants better understand the design context and constraints. In this case, starting from the paper floor plan and then diving into the XR world could prepare one's mind for the XR world. We could consider providing them with both 2D floor plans and an XR experience. The switching between mediums could enrich the creative and imaginative space because they are experienced in two worlds.

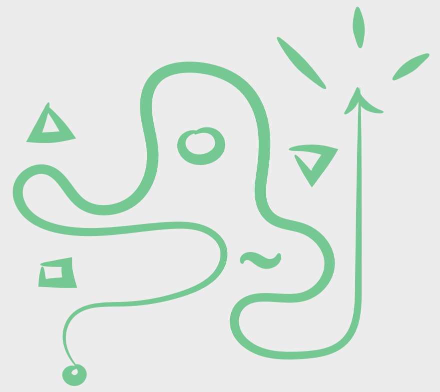


Engage end-users

With regards to engaging end users, it is both a question of where and how to involve them in the design process. As mentioned in the workshop, and by Sanders & Stappers (2012) in Convivial Toolbox, involving end-users like flight attendants can be of great benefit for gathering valuable insights and feedback. It is really the core of what co-creation is all about. To make the most of the time with end users in the process, clear boundaries and tasks must ideally be set into place.

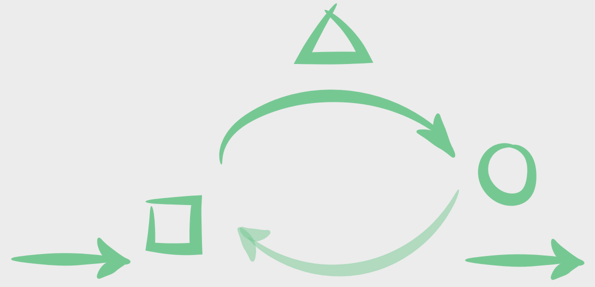
Create scenario-based tasks

To help participants better understand the context of their designs, we can consider creating scenario or story-like based tasks in XR that simulate real-world situations. Researcher Sandhya Santosh is applying this method in her PhD research. This can help participants design solutions that are more practical and aligned with the needs and challenges of the specific environment, in this case, the galley of the Flying-V. It is also a way of introducing a constraint or boundary to the XR environment because the scenario can act as an intangible boundary.



Iterate and refine

Iteration and refinement is an ongoing process throughout the design process. It can be seen as an overarching principle that has no set place in the design process but keeps on returning. It could form a bond with the collaboration points in the co-creation process and allow participants to iterate and refine their designs based on feedback received from other participants in the XR world. This also ties into the validation step of certain concepts, where participants are able to immerse themselves in XR and validate certain concepts before re-iterating them and in turn leading to more sturdy user-centred designs that address the needs and challenges of the intended users.



4.5 Ideation for Testcase

First, let us look at the potential areas where XR could be implemented in a co-creation process judging from the earlier findings. Although the steps of a co-creation process are never exactly the same, we will go for a rough overview based on the steps taken in the pilot workshop. The green arrows indicate where XR may be of benefit according to the findings up till now.

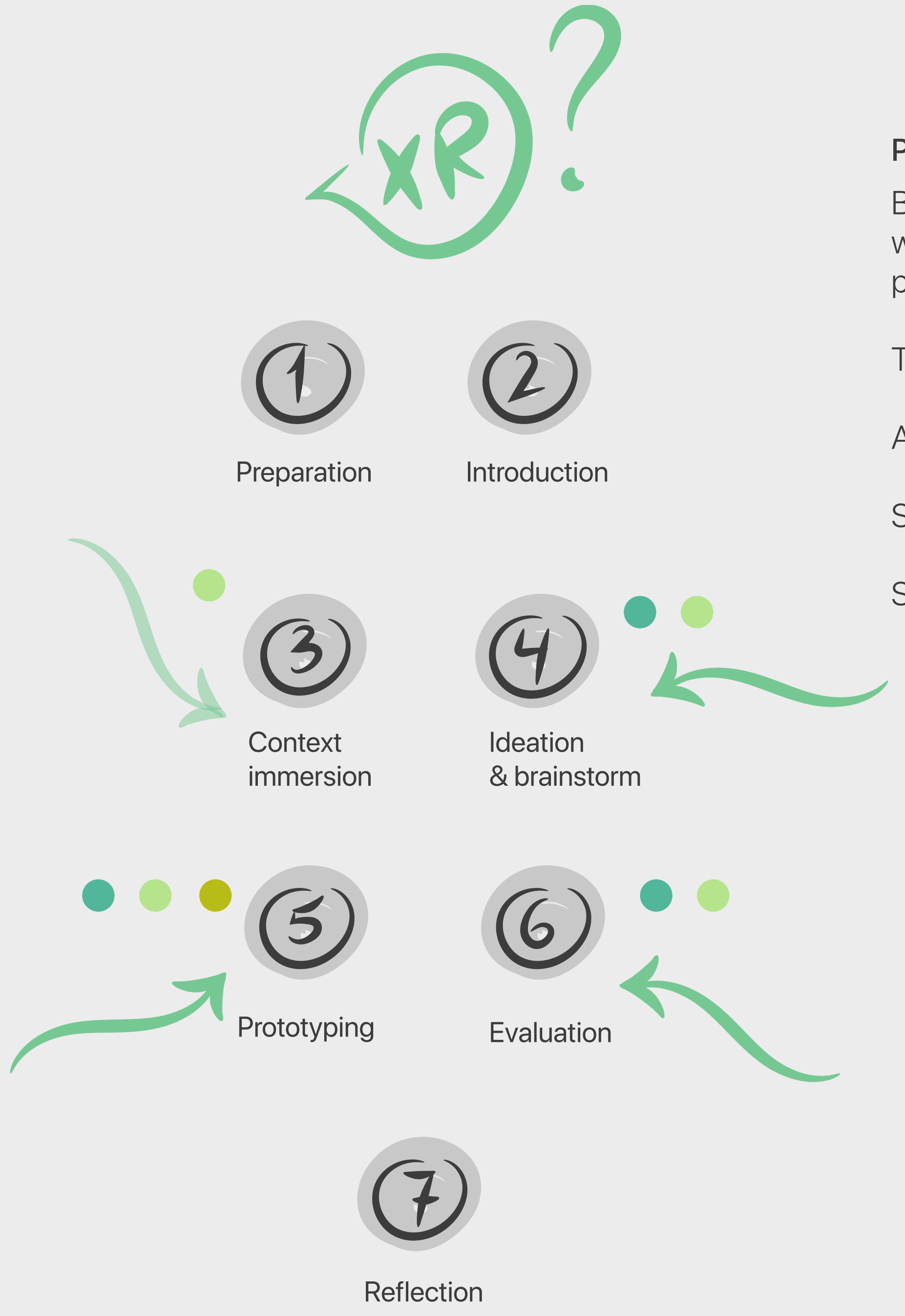


Fig X: Rough overview of codesign process

Potential Directions

Based on these first findings three main directions with regards to fitting XR into the codesign process have been drafted.

These are:

A hybrid of physical and XR elements.

Strictly XR elements with a facilitator leading

Strictly XR elements with minimum facilitation

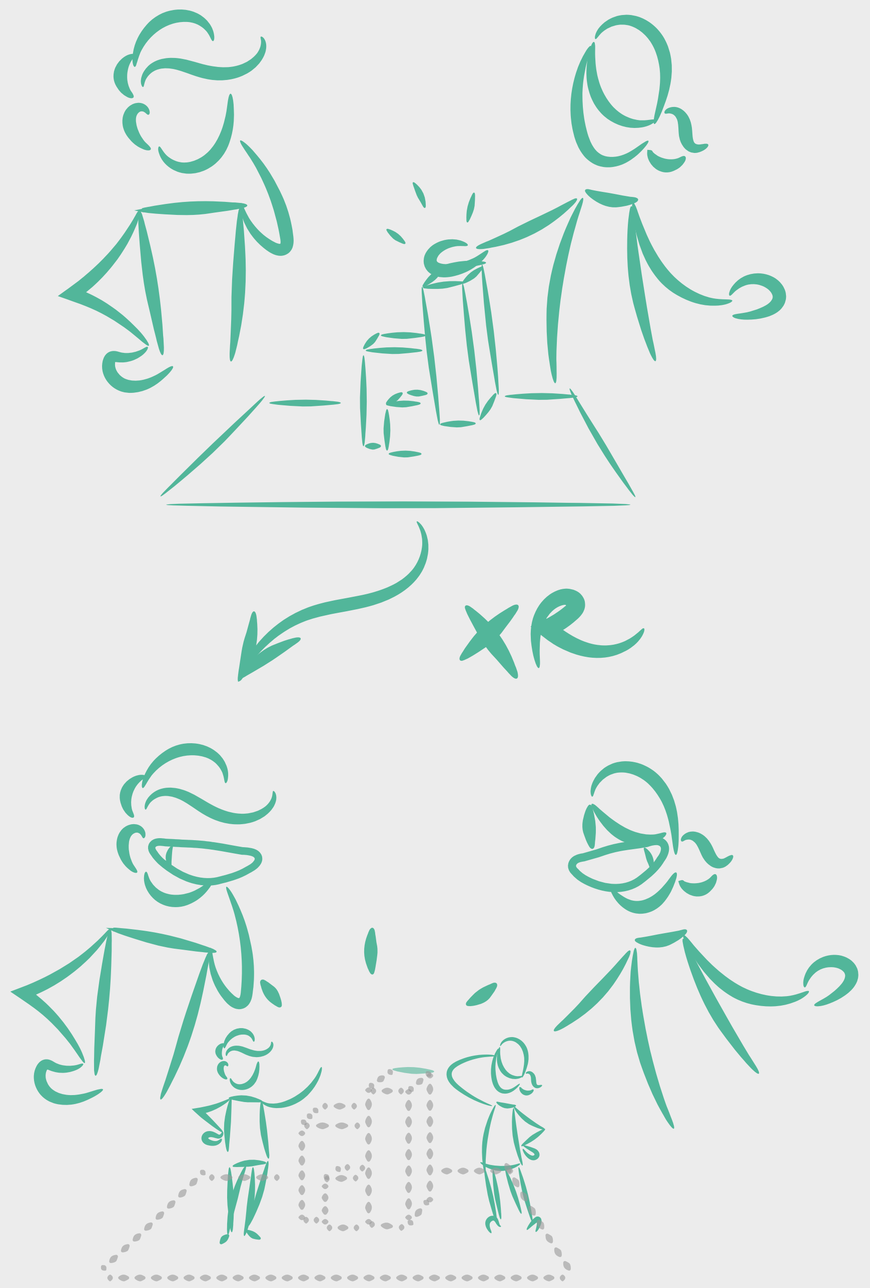
A hybrid of physical and XR elements.

This idea combines the physical world with the virtual world. According to App (2011), people communicate emotions nonverbally in three different ways: body, face and touch. These subtleties could be lost when wearing an XR device such as a head-mounted display (HMD)—potentially missing key moments in the interaction and collaboration between the participants in the workshop.

A combination of physical and virtual objects could unleash the potential of both worlds. In the pilot co-creation workshop, Lego was mainly used to build a low-fidelity mockup of the galley for the Flying-V. The Lego bricks were then mocked up in the virtual world for participants to see their creations at full scale.

The facilitator did this. A potential to lower the threshold of using XR in the design process could be using physical objects that are directly connected to the virtual world. This would mean that participants could play and ideate in the real (physical) world just like one would do when building a Lego creation. The position of the bricks in the physical world is then updated in real-time in the virtual world. Participants are invited to build and experiment in the real world whilst being able to jump in and out of the virtual world to verify whether their ideas are what they intended them to be.

This would mean a system is needed that connects the physical elements to the virtual world in order to successfully display in XR what is built in the real world.

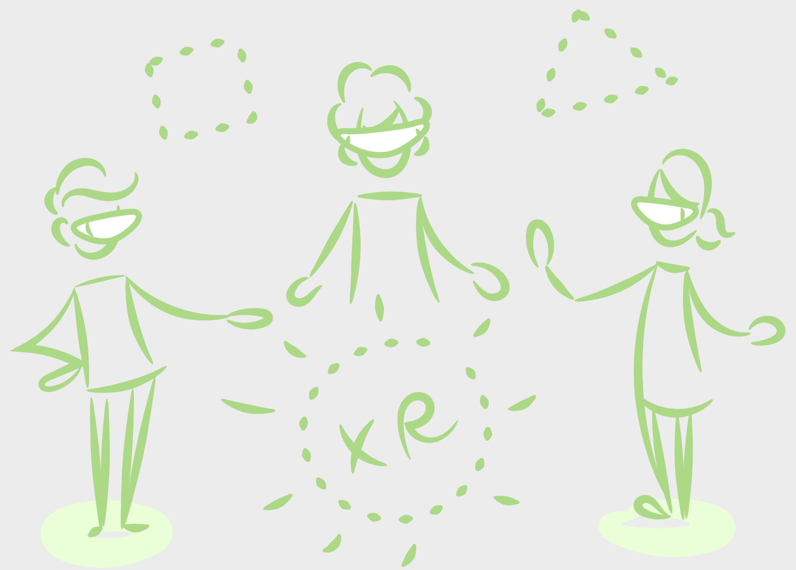


Strictly XR elements with a facilitator.

This can be seen as the virtual equivalent of the former idea. Removing the physical 'playground' and jumping straight into XR. All participants, including the facilitator, find themselves in the virtual world. Ideally, in the same physical space so they can walk around in the virtual world together.

The workshop facilitator is awarded a bigger role in this concept. The workshop facilitator would, in this case, be the 'worker' who creates and places elements in the virtual space according to the wishes of the participants. The participants can walk around and view virtual elements but not manipulate them themselves. The facilitator only has this power. However, the participants are encouraged to think out loud and give instructions to facilitate the creation of their ideal concept.

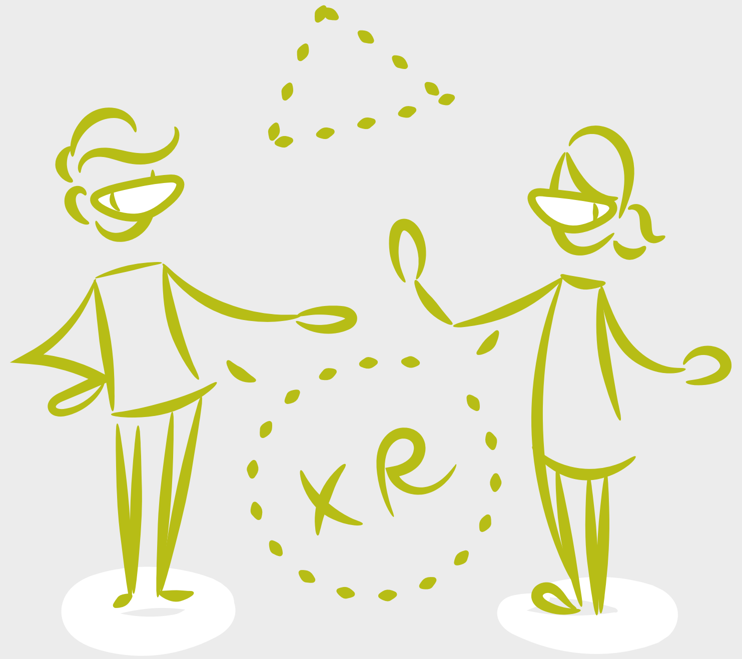
The participants require no technical know-how since the facilitator controls the virtual elements, lowering the threshold for using XR.



Strictly XR elements with minimum facilitation.

Only using XR with minimum facilitation is a double-edged sword. It could potentially unleash great creative potential amongst the participants. Manipulating the virtual world and its elements together. However, the need for technical know-how could outweigh and counteract the benefits of working this way.

To make this work, the virtual world must be as easily understood as possible. Ready-to-use pre-made elements could make this way of working easier. A virtual pile, stash or warehouse with elements that could be grabbed and positioned in the virtual world might make this idea more feasible. The facilitator would only be in the virtual world for troubleshooting or questions, with a short tutorial before the session participants could be able to work in this way. However, the potential unfamiliarity of the technology with the participants could cause problems.



Next Steps

In the next steps, one or more of these methods will be tested to see how effective they are. Observations and questionnaires about the session will determine how effective workshop iterations are.

Designing the XR & Co-creation Method

5

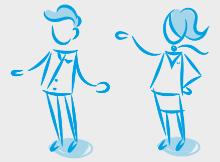
5.1 Prototype Iteration Workshop 1

Introduction and Overview

The first workshop hosted after the pilot workshop was set into place to be the first session to iterate on. It is also the first workshop with actual KLM flight attendants. It is the first workshop in a series of five and is intended to see if the current workshop setup is sufficient enough or lacking in any way to continue to the next session. The main objectives include seeing how flight attendants differ from engineers and designers within a co-creation session. In this workshop, a mixture of physical and virtual elements is used.

Objectives:

The first workshop focussed on how XR can play a role in the co-creation process with actual end-users—identifying bottlenecks and other potential problems to be addressed and improved on for the next session.



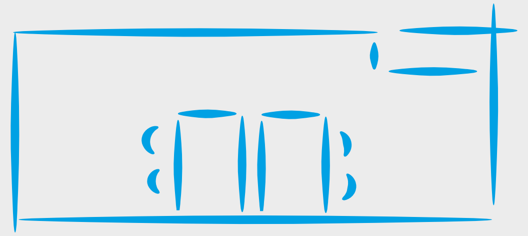
Participants:

The workshop was organised by the author in collaboration with KLM. The participants consisted of two flight attendants from KLM. One male one female. Both with experience within the entire aircraft fleet of KLM. With their combined extensive experience, they could pass on great deal of knowledge concerning galley usage and issues they faced. Because of the bureaucratic nature of recruiting flight attendants through official channels, the author sent out recruitment messages via social media, unofficially approaching KLM flight attendants. For this session, one participant recruited through Instagram joined the session.

Fig 24: An impression from PIW 1

Setting:

The workshop was set up in a meeting room in one of the offices of KLM building 107. The meeting room was rectangular shaped and had a set of two tables and four chairs. These were used during the non-XR part of the workshop to write Post-It's and lay out the physical elements and floorplan of the Flying-V. The virtual world was set in an infinite white grid world in the program Gravity Sketch. In here virtual elements could easily be manipulated and rearranged.



Preparation and Materials:

To prepare for the workshop a combination of both materials facilitating the workshop in the physical and the virtual world were needed. These included:
- A small water filled balloon used as an energiser
- Post-It's
- A wide range of coloured fine liners and markers
- Painter's tape
- A 1:20 scale top view of the Flying-V plotted on 2x 180*90cm paper at the Faculty of Architecture.
- A selection of to-scale 3D-printed blocks modelled in Blender resembling galley elements such as trolleys, half-sized trolleys, ovens, coffeemakers, containers etc., labelled with a Dymo label printer.
- Ambiguous/Non-labelled 3D-printed blocks.
- 3x Meta Quest 2 Headsets including controllers with Gravity Sketch Installed on each device. The author's own device, a borrowed device of a friend of the author and a device borrowed from the XR-zone in Delft.
- Spare AA batteries for the Meta Quest 2 controllers.
- Powerstrip and chargers to keep the HMDs charged at all times.
- Stickers to cover up the proximity sensor of the HMDs to avoid them going into sleep mode.
- 3 separate Gravity Sketch licences to enable collab mode with 2 or more people.
- Access to the TU DELFT EDU hub in the Gravity Sketch environment.
- A 3D model of Flying-V for use in VR adjusted by the author from an existing model in Blender
- Virtual 'block elements' representing the 3D-printed blocks in the virtual environment. Modelled in Gravity Sketch and Blender.
- A small design brief on A4
- 2X printed concept floor plans on A4 as inspiration.

Workshop Structure:

"Immerse in the context."

The workshop commenced with a small introductory presentation held by the facilitator, the author of this thesis, who is also the designer. The workshop consisted of three main parts: immerse in the context, design the new context, and immerse in the new context. The first part of the workshop 'immerse in the context' is meant to dive into the current context of using a galley. It was all about recalling the galley experiences of the crew.

The purpose of this phase was to prime the participants for the midsection of the workshop, designing their ideal galley. A short energising session was performed where participants had to come up with words that they associated with a word the previous participant had said. Subsequently, a brain dump was conducted where participants wrote all their positive and negative experiences concerning the galley usage.

These were grouped and categorised by the facilitator and left on the wall for further reference during the workshop. After a short break, the participants were introduced to the Flying-V shown in two videos. These were selected to be an inspiration for the following exercise.

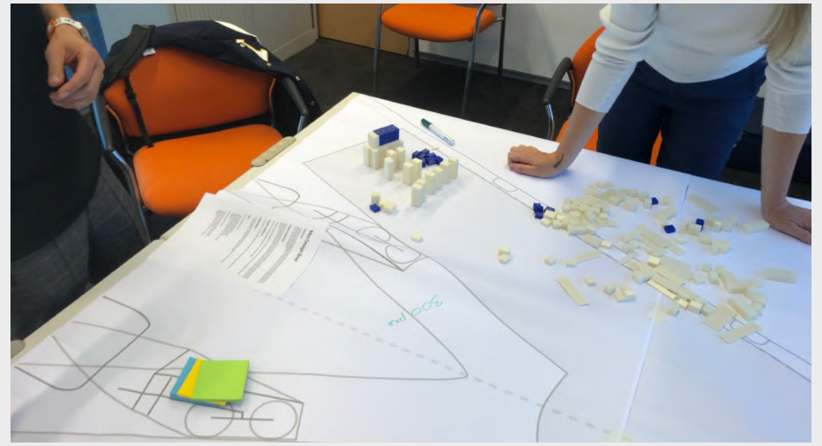


Fig. 25: Flight attendants at work with the physical objects.

"Design the new context."

The room was rearranged by placing tables together and laying out the floor plan of a printed top view of the Flying-V. The 3D-printed blocks were placed on the table to act as surrogates for objects inside the plane. The facilitator then introduced the exercise. Participants were instructed to develop ideas of where to place galleys in the Flying-V and what these should look like. They were also instructed to use the 3D-printed blocks as a guide and to draw or write on the large top-view paper.

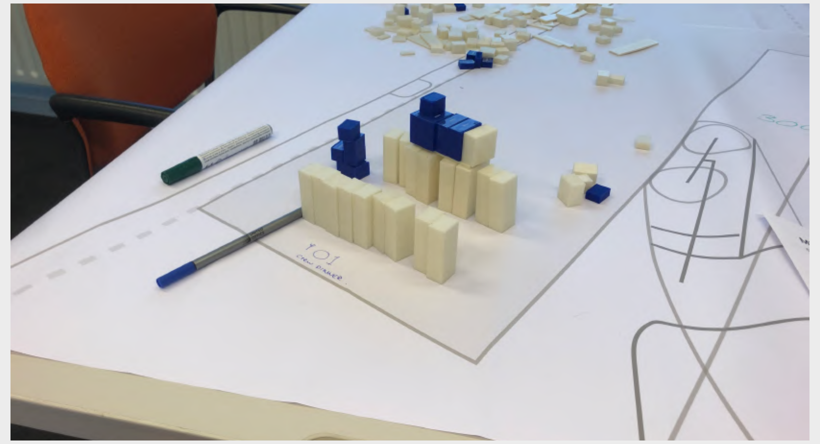


Fig. 26: The very first PIW galley design.

Facilitation and Interaction:

The facilitation took place by one designer, the author of this thesis. The facilitator leads the workshop by introducing the topic and the three pillars of immersing in the context, designing the new context, and immersing in the new context. Participants looked very interested and engaged and had a lot of ideas about how a galley should change. The facilitation also meant the designer had to take care of the technical aspects of the HMDs, modelling live in VR and setting up a collaborative space all within a limited timeframe.
Participants could follow instructions until the 'design the new context phase'. In this phase, the designer gave them the responsibility and freedom to develop their own galley design. The participants faced some starting issues with the exercise and had to be guided by the facilitator in developing designs. They collaborated effectively together. With some help they could work out galley positions and contents of galleys. This led to the placement of physical blocks in different cabin areas.
During the 'immerse in context' phase, all the participants, including the facilitator, wore the HMDs to immerse themselves in the virtual world. This virtual world first consisted of an empty white grid space with blocks representing the galley which could be moved around. The participants were not given any controllers for controlling their views or objects, the facilitator remained in control.

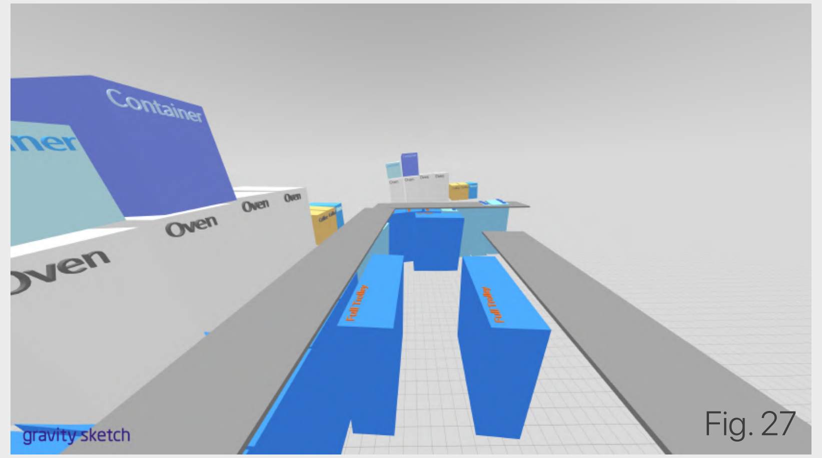


Fig. 27

Participants remained stationary during the viewing in VR. The facilitator asked questions about their desired placement of objects in the galley. They remained passive viewers and needed to be encouraged to interact or speak about the virtual elements. By asking questions the facilitator learned of their preferences.
The second part of the immersion consisted of the participants being immersed in a basic Flying-V model. In this model, chairs were laid out according to Wamelink's thesis (Wamelink, 2021). This gave the participants more of a feel of how things should work and how the placement of different objects could work. To prevent motion sickness, the facilitator turned on the mixed reality mode so participants could still see the physical world around them.

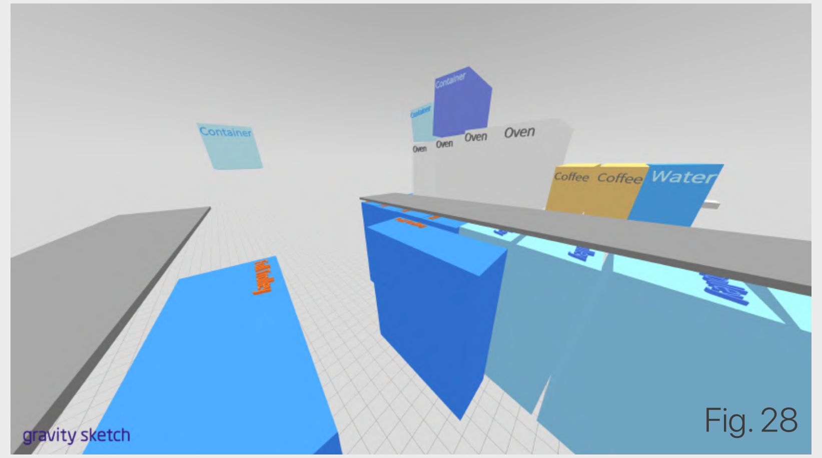


Fig. 28

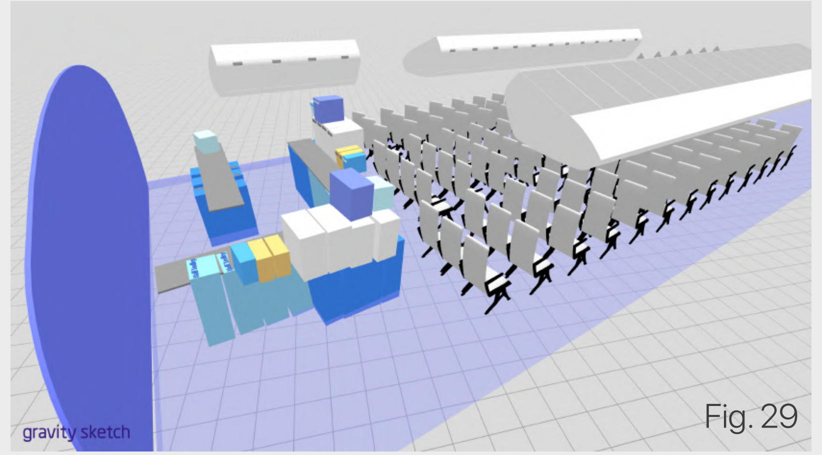


Fig. 29

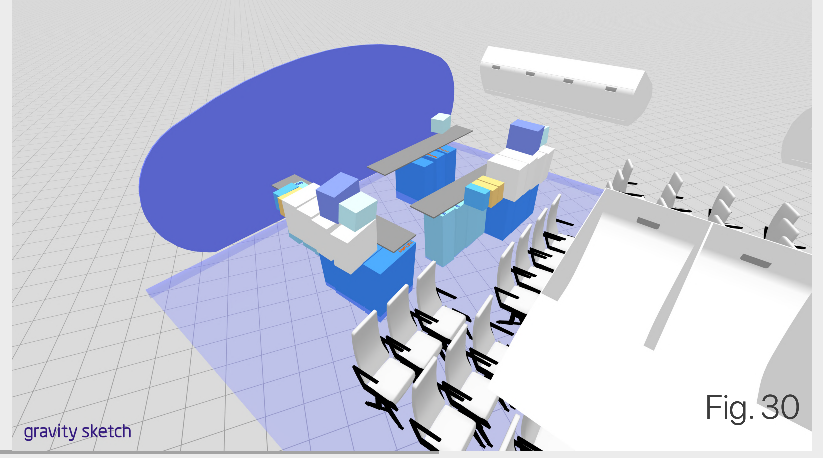


Fig. 30

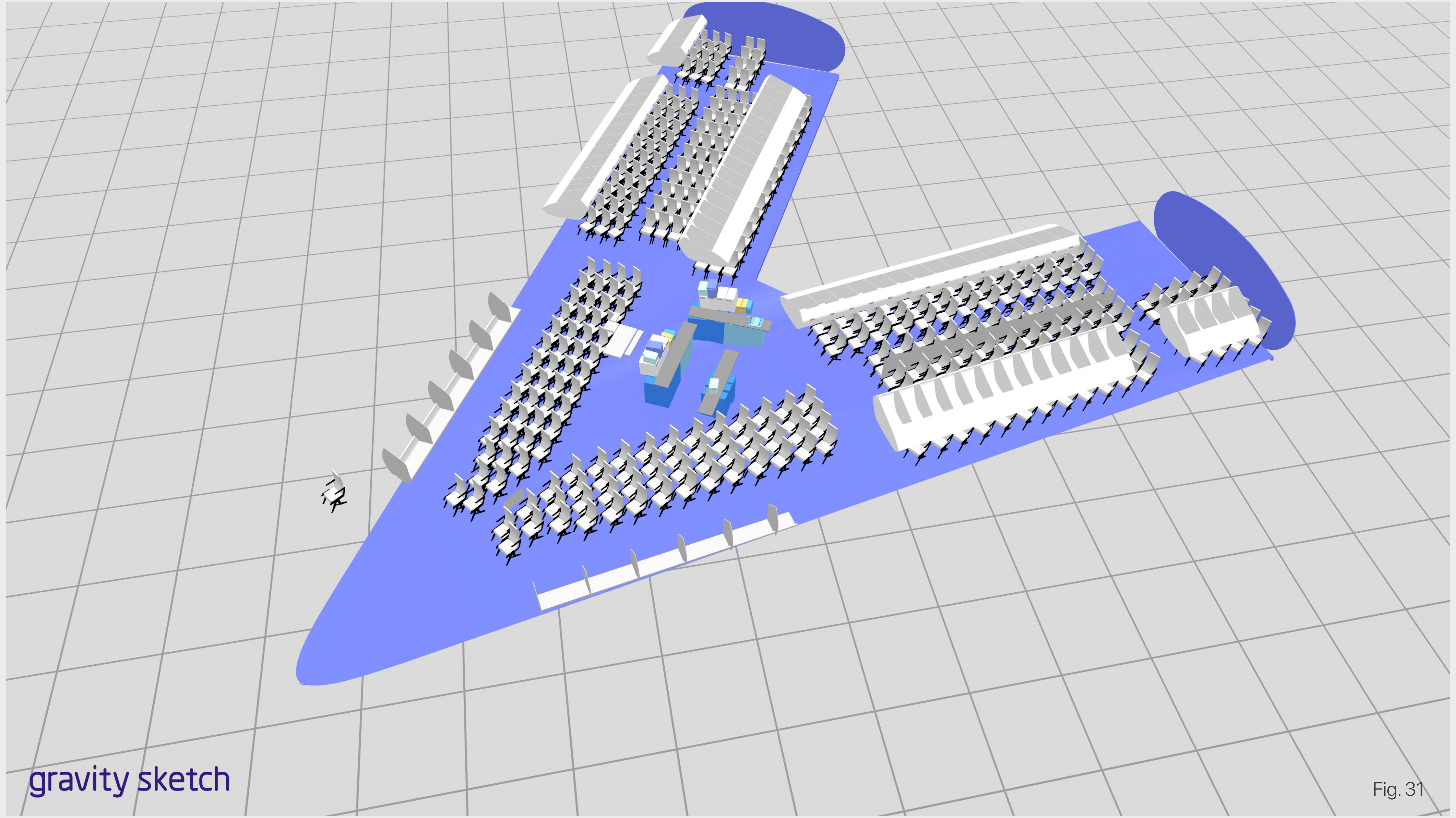


Fig. 31

Fig. 27-31: Various screenshots from the galley PIW 1. Flight attendants were mostly concerned with the galley itself. Placement within the aircraft came secondary

Observations and Data Collection:
Data was gathered by using a voice recorder app on an iPhone and the session was recorded through a Sony Handycam mounted on a tripod in the corner of the room filming the whole session. Unfortunately, the iPhone voice recorder stopped working. This meant only Handycam was recording in the end. This video data was then converted into an audio file. The audio file was fed into an audio transcription software to make it easier to search for specific quotes. The audio was into MacWhisper, a program only compatible with the newest generation Apple Macs. A device not in the possession of the author so this device had to be borrowed.

Fig. 32: Flight attendants immersed in XR

Key Findings
The session demonstrated the difference between working with actual flight attendants instead of designers and engineers.. In contrast to the designers, they were very much service minded and knew exactly how many trolleys, ovens, other equipment and flight attendants were needed to serve a given number of passengers. The session also demonstrated that the flight attendants as opposed to designers needed more guidance when designing. The became apparent when after a few minutes no designs were built yet and the asked the facilitator for help. When this was provided, the physical blocks proved to be an effective medium to build up galleys and expedite ideas. Participants did however only use the blocks in non-ambiguous ways, meaning that unlabeled trolleys for instance were still seen as trolleys. This led the participants to believe that the catering world would look the same in the future and thought this might be a too conservative way of designing for the future.

In XR the flight attendants mentioned that it became clear how many problems could arise when working in this aircraft. The realisation of two cabins dawned upon the participants only in XR. Especially when immersed in the basic model of the Flying-V. Making the physical galley in blocks proved to be an essential step they needed to grasp before actually bringing participants into the virtual world. Participants immediately mentioned they felt they had not thought out their designs well enough on paper and blocks. They also mentioned being overwhelmed by the number of passengers surrounding them if they were flying in this plane.

Participants' Feedback:
Quotes mentioned by the participants included:

"We had to think this out better on paper before we came into VR - the step to VR is quite big"

"You really feel the limitedness of an aircraft when in VR"
" It really is two separate cabins or two separate aircraft. If I for instance need your chicken from the other side we can't really communicate"

"This is really based on how things go right now, I can imagine the catering world being very different in the future."

" In VR it really becomes clear how many problems could arise when working in this aircraft"

Participants furthermore did not seem to express great exclamations of being impressed the first time when they were immersed in XR without the aircraft surrounding them.

Reflection and Analysis:
This first workshop was meant to be a baseline for testing with the cabin crew. It provided insights into the timing and setting up of the materials. It also highlighted the difference between working with designers/engineers and adapting the role of flight attendants and actual flight attendants.
More guidance or tools would be needed in the next session with the cabin crew because of the creative block they faced when actually being allowed to design. The author had posed and 3D-printed two scaled mannequins of flight attendants but had forgotten to bring them to the workshop. This may have helped speed up the creative process since a human reference would have been beneficial. Setting up the headsets and connecting them to the WiFi network and setting up a collaboration mode in Gravity Sketch also took more time than expected with headsets being deactivated mid-setup. The switch from the physical world to the XR world was something that in the next workshop, would have to be more of a one-to-one experience, which means that the creation in XR did not entirely reflect the physical creation. This was due to the fact that the physical creation was not entirely ready and due to time the workshop had to move on to the XR phase in order to be finished on time. Creation was done more or less twice, once in the physical and once in the XR world. In general, the whole session took more time than anticipated, running over by half an hour.

Implications:
The first workshop showed that using blocks to create a proposal for a design was an intuitive way of quickly creating a design. There should have to be more emphasis on the ambiguous character of the blocks by the facilitator in future sessions for them to be used more freely. Also, the facilitator might have to join part of the creative session to guide the participants. The facilitator in charge of manipulating and moving particular objects in the XR space was also shown to be an efficient way of working and adjusting designs in real time. The immersive character of XR made participants more prone to thinking about other solutions than they had thought of during the physical session. The workshops were time limited and the flight attendants voluntarily gave up their free time. A longer co-creation session with physical blocks and XR could potentially lead to interesting outcomes.

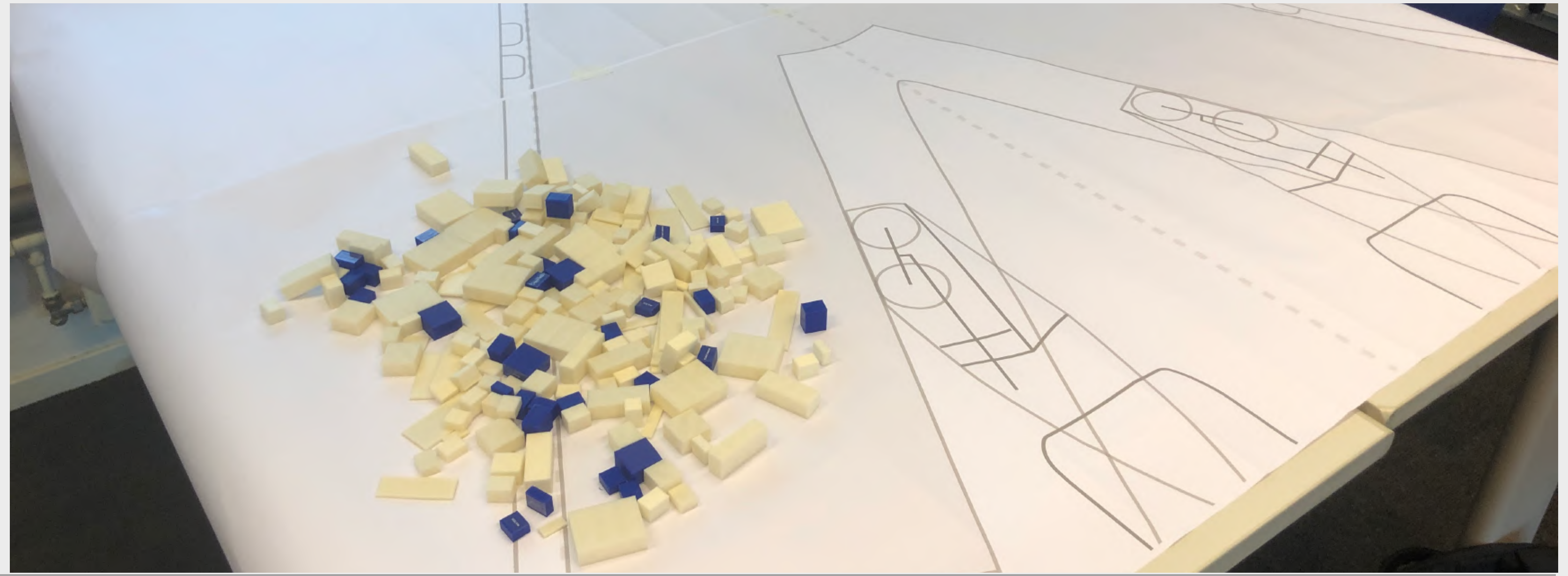
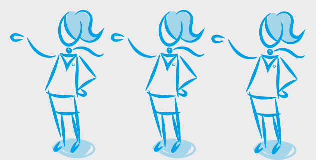
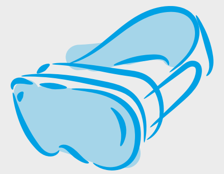


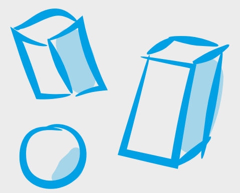
Fig. 33: The initial set up of the physical section of PIW 1

Summary:
It seems that combining physical blocks and XR elements could lead to exciting outcomes when exploring novel designs and future scenarios. However, the switch from the physical to the XR world needs to be more seamless and in future sessions, participants need more guidance in actually designing with blocks.

5.2 Prototype Iteration Workshop 2







Introduction and Overview

The second co-creation workshop was hosted a week after the first one at KLM's 107 building. As with the first workshop, it also took place in the same office. It is the second session with actual KLM flight attendants and the second in a series of 5. It was hypothesised that additional materials and instructions needed to be provided based on the preceding workshop. A more seamless transition from the physical blocks to the virtual world is another concern to be addressed in this workshop

Objectives:

The main objective was to test and see if combining physical blocks with XR could lead to enhanced results as opposed to just using one of the two techniques. The second objective was to smooth out hurdles from the first session and to see if more guidance from the facilitator could lead to better results. These bottlenecks included technical issues with the headsets turning off at random moments and participants hence being removed from the collaboration session. More guidance in the initial design phase is required to overcome creative blocks with the participants. The ambiguous nature of the building blocks should be emphasised.

Participants:

Participants were recruited through a newly established contact at KLM and the author organised the workshop. For this session no flight attendants were recruited through social media. In this co-creation session, three flight attendants joined, all of them female. All of them had experience on continental and intercontinental flights. Amongst them, they had worked on the entire fleet of aircraft at KLM. As in the first workshop, their extensive experience also led them to mention many of the benefits and disadvantages of working in a galley.

Setting:

The workshop was set up in the same meeting room as Workshop 1. There had been no alterations made to the room since the last workshop.

Fig. 34: The braindump stage in PIW 2

Preparation and Materials:

The same materials were needed as for the first workshop with the addition of some extra features. These being:

- An extra Meta Quest 2 HMD with Gravity Sketch installed.
- An extra Gravity Sketch licence with access to the TU DELFT EDU environment
- A Floorplan of the Flying-V 1:20 scale with a greyed-out seat plan for extra reference and a better understanding of a potential cabin layout.
- 2X 1:20 scale 3D-printed mannequins of flight attendants with a minimum converted height of 158 cm and maximum converted height of 190 cm. Modelled in Gravity Sketch and Blender.
- 30X 1:20 scale low poly 3D-printed chairs modelled in Blender
- Additional materials such as foam board and tape were provided to stimulate a more freeform way of thinking.

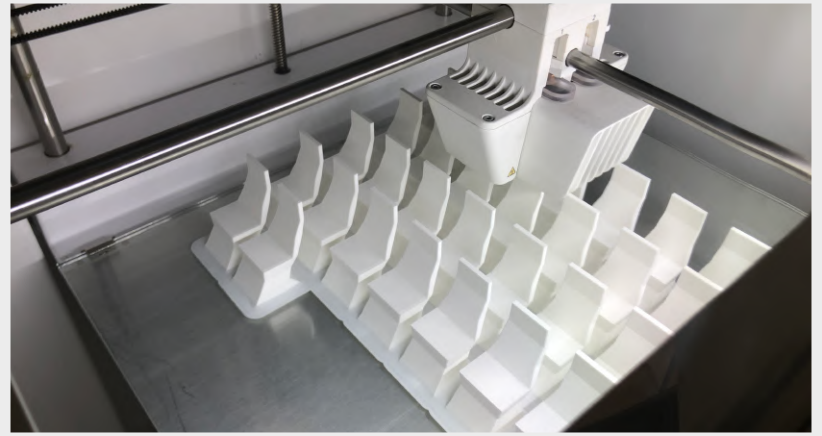


Fig. 35: 3D printing additional assets for PIW 2: Chairs

Workshop Structure:

The workshop followed the same steps as the previous workshop: Immersion in the context, designing the new context and immersion in the new context. Only minor alterations were made. Before the session started the facilitator made sure all HMDs were fully powered and connected to WiFi.

The immersion in the context phase followed the same steps as the previous steps. There were more ideas generated during the braindump due to the extra person in this session and the "Galley Challenges" poster by Ir. Maxim Smulders was shown after the braindump as extra inspiration.

While designing the new context phase, images of futuristic galley designs were displayed on a notebook screen. In the previous workshop, this was where participants struggled the most. This was due to the fact that an empty cabin on a 180*180cm sheet of paper was perceived as intimidating to fill. Here the choice was given to design on a similar sheet of paper as provided in the first workshop or to use a 180*180cm sheet of paper with a greyed-out floorplan as a reference. When provided the option, surprisingly to the facilitator the flight attendants chose the blank option and said they would only use the floorplan if they needed extra inspiration.

The facilitator asked if they would feel confident designing from scratch. After an affirmative answer, the participants got to work by themselves. They were instructed on how many passengers could board the aircraft and the type of flight. An afternoon flight from AMS-JFK. This scenario helped them on their way to coming up with new galley designs.

After creating a galley design the flight attendants presented their work to the facilitator explaining their rationale for the placement of objects and structures. They had also drawn on the floorplan to indicate objects that they could not build such as walls and curtains.

The facilitator quickly mocked up the design in XR using Gravity Sketch and arranged the elements precisely as had been done by the flight attendants with the physical blocks.

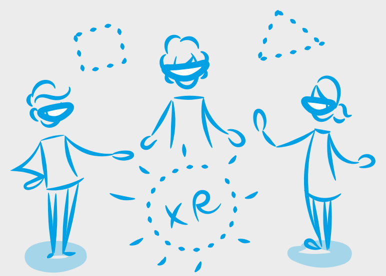
Due to time constraints, two flight attendants had to leave the session and could not join the XR immersion in the new context part of the workshop. However, fortunately another flight attendant from Workshop 1 joined this part.

In the final part of the workshop the facilitator and one flight attendant put on an HMDs to immerse themselves in the newly created design. Feedback was given to the facilitator and new ideas were modelled live with the flight attendants viewing the facilitator creating virtual shapes.

Facilitation and Interaction:

The first part of the workshop served to allow participants to become familiar with the Flying-V and co-creation in terms of galley design. Participants complied and actively asked questions. In the design phase of the workshop participants discussed a lot amongst themselves and immediately started using the 3D printed blocks for building their designs. The facilitator stressed the ambiguity of the blocks. After a few minutes, the participants had laid the groundwork for their ideas and the facilitator only played a minimal role by asking how they were getting along and checking if certain members were not overpowering too much. There were no startup problems whatsoever and the participants seemed to have a clear idea of what they wanted and used the blocks to indicate existing and non-existing parts of their design.

Once the participants felt satisfied with their design the facilitator asked them to present their design. This was done by going to each area of the plane on the printed-out floor plan and describing what had been built there. After this description and building, participants were offered a break in which the facilitator mocked up the blocks that were used in the physical world and created them in the virtual world. Due to time constraints, only one flight attendant remained present for the immersion in XR with the facilitator.



Instead of starting in an empty grid world, the facilitator made the choice to lay out all the galley elements in the virtual model of the Flying-V, immersing the participant directly in the aircraft. This gave flight attendants a better sense of scale and limitations. For continued flow of the workshop and technical ease, a particular point in the aircraft was chosen to be analysed. The location of the participants in the virtual Flying-V was set to the middle of the Flying-V.

Similar to workshop 1 the controls were in the hands of the facilitator with the participant fulfilling an instructional and observational role, but not being able to manipulate the world around them. The participant came up with many ideas without the facilitator having to encourage them a lot. These ideas were synthesised while standing in the created 'bar area' of the aircraft. They were built on the original foundations laid out in the physical part of the workshop.

Fig. 36: The 3D printed blocks used to draft the layout and placement of the galleys

Observations and Data Collection:
Data was gathered using a Sony Handycam mounted on a tripod in the corner of the room filming the whole session. This video data was then converted into an audio file and underwent the same process as workshop 1.

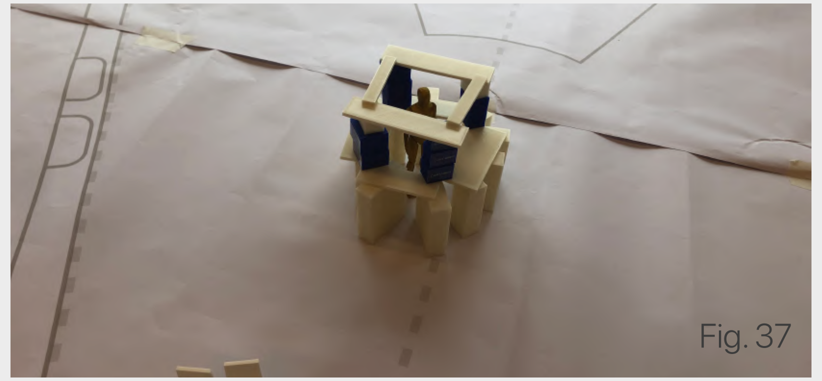


Fig. 37

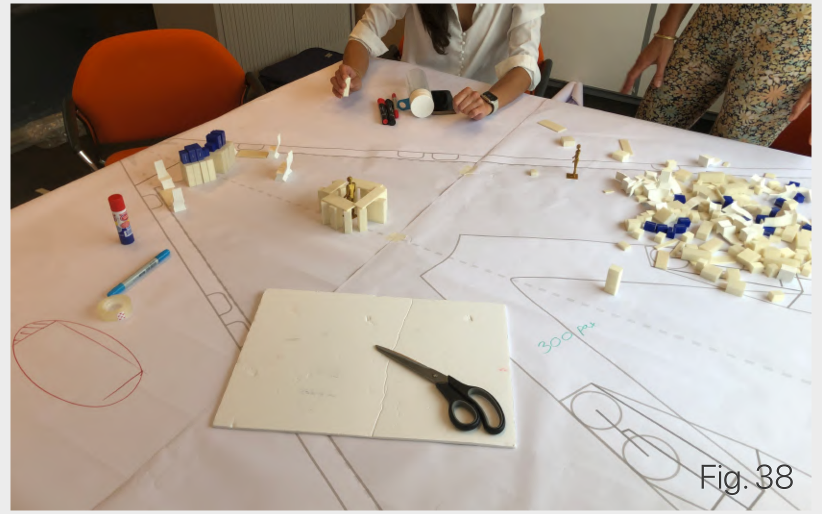


Fig. 38

Fig. 37 & 38: Flight attendants designed a bar in the mid. of the aircraft. This also made for a good look out point

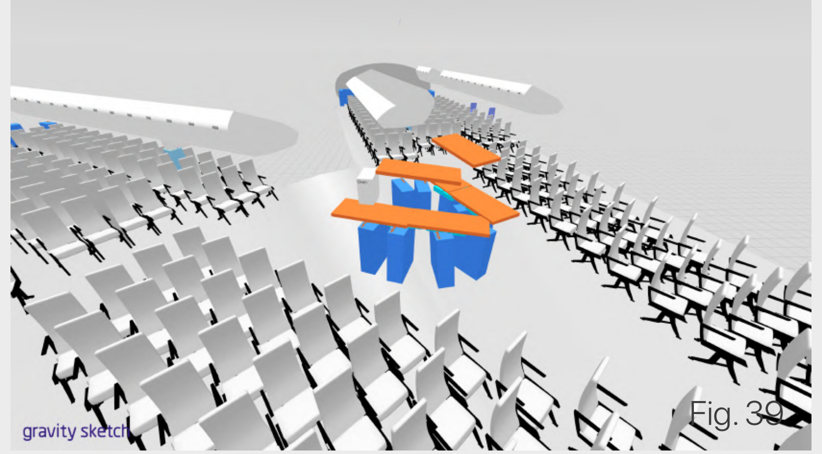


Fig. 39

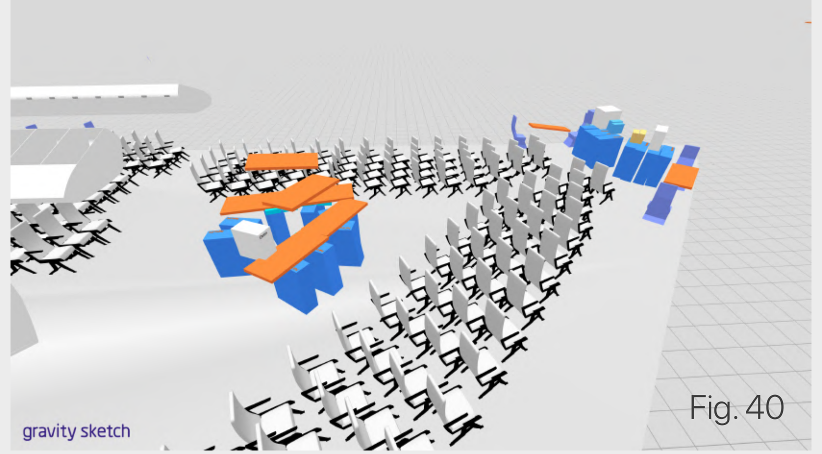


Fig. 40

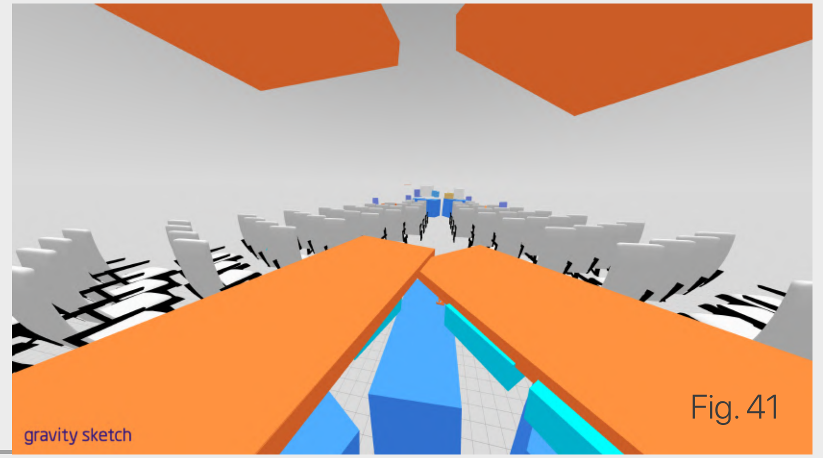
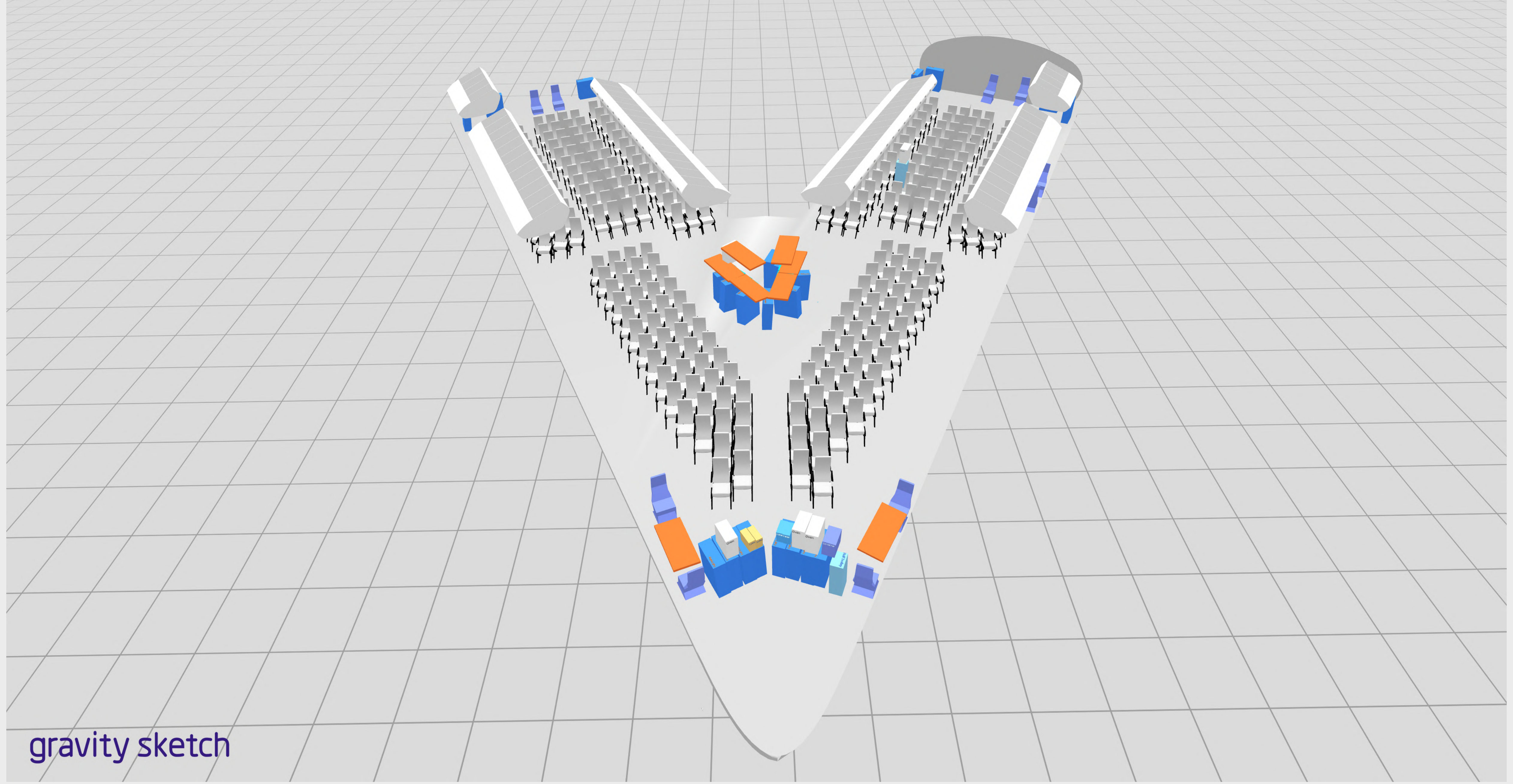
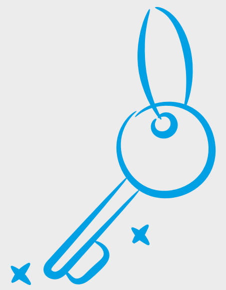


Fig. 41

Fig. 39-41: In XR flight attendants required the layout of the bar to be changed.

Fig. 42: The layout of the bar was preferred to be V-shaped, in line with the design of the aircraft. This was only realised in XR. Also the need for the option to have drinks hanging from the top of the bar and the need for an exit were only realised in XR.





Key Findings:
The session showed that working with different flight attendants can differ significantly. Something the facilitator was not expecting prior to the session. Right after the facilitator had instructed the participants to start building with the physical blocks they immediately started building hands-on.
The low fidelity blocks (lofi) worked well to synthesise ideas quickly. The participants noticed they had a shortage of blocks for some of the things that they wanted to create. Additional ideas were added to the existing concept when immersed in XR. Participants had created a bar area in the centre of the aircraft. Whilst in XR standing in the bar they noticed that maybe it should not be a bar but an issue point. More ideas came to mind such as adding drawers under the work surface of the bar. Or that it would be convenient to have drinks hanging from the ceiling for easy access, like a cocktail bar. In XR the possibility to build upon the physical ideas became apparent, opening the imaginative space of the participant. Whole ideas were even altered completely in XR since it became apparent they would not work well whilst the participant was immersed.
Whilst being engaged in their own design in XR the limitedness of the aircraft was experienced as being less severe than what was experienced in workshop 1.

Participants' Feedback:
Quotes mentioned by the participants included:

"Maybe this should become an issue point"

"You know what would be handy if you would have a lot of drawers under the worktop here"

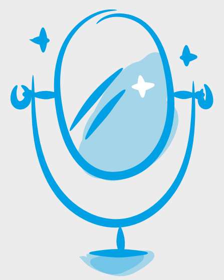
"Maybe we can hang the drinks from here?"

"This might be too high for some flight attendants. For me, it would be perfect"

" I think it would be nice if you can exit somewhere here. Now I feel a little bit locked up

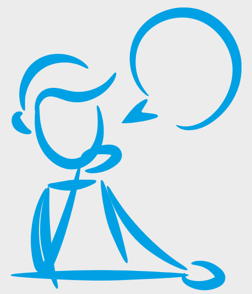
"Maybe we should hang a curtain here?" "No that's actually not the way I meant it"

Whilst immersed the participant proposed to alter the whole concept of the bar and make it in such a way that it was accessible from the back instead of it being an object resembling a 360 degrees stage. From this idea, the idea of the V-bar came into existence, thanks to the participant feedback in XR.



Reflection and Analysis:
This second workshop was an iteration of the first workshop. The second workshop made clear that XR can aid in coming up with additional ideas based on the existing ideas made with the physical blocks. This became apparent while immersed and new ideas started emerging based on what participants were seeing, feeling and doing. New elements such as the 3D-printed chairs and mannequins were extensively used and added to a more lively design experience. The design being translated on a one-to-one scale from the physical world to the virtual world helped to create a more seamless transition from physical to virtual because participants immediately recognised their design in XR. The baseline of the first workshop was in place but additional materials and resources were added to this session. Because some of the participants had to leave early due to a logistical miscommunication a lot of the extra materials were not used, such as the extra HMD and extra license. Availability of participants was a limiting factor in this case which can make co-creation more complicated than traditional design.

Also, the facilitator did not yet find a foolproof way to keep the headsets from going to sleep unwanted while preparing for a collaboration session.



Implications:
Using XR and 'make tools' in co-creative design seemed to have benefits that include enhanced collaboration, increased creativity, and an enriched understanding of the design context. By using 'make tools' within an XR environment, participants could quickly adapt and adjust their designs based on feedback and personal insights. There was an increase in engagement and creativity, which likely had a positive effect on the final design outcomes.
The second workshop showed that physical blocks could be used as an initial proposal for a design. With good instruction participants can let go of the predetermined roles the blocks could have and see them as ambiguous and as existing parts of a galley set-up. Then in XR participants were able to build from the ideas created in the physical space. This clearly shows the added value XR can bring to the table by stimulating participants to think more creatively while they are immersed in the virtual world.

Summary:
This second workshop indicates that the use of physical blocks and XR elements can be used in combination to showcase ideas on a different level. The physical blocks can be used for initial design stages and roughly 'blocking out' areas and concepts in a hands-on way quick and dirty kind of way. These ideas can be expanded on and refined in XR. The question remains whether it is easier to do the blocking completely in XR or not.

Fig. 44: The facilitator designing the physical layout in XR.

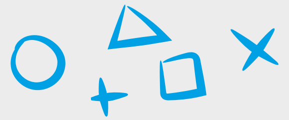
Fig. 43: The facilitator moving objects while being observed by flight attendants.

Fig. 45: The realising she wants drawers in her design.

5.3 Prototype Iteration Workshop 3

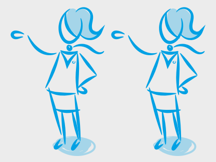
Introduction and Overview

The third co-creation workshop was hosted two weeks after the first second one at KLM's 107 building. As with the second workshop, it also took place in the same office. It is the third session with actual KLM flight attendants and the third in a series of five. It was hypothesised that building each other's designs in a different medium would yield additional ideas.



Objectives:

The main objective was to see if splitting the group in two would lead to different results than before. Here the idea was proposed to have half the group building in XR and the other half in the physical world. The goal of this session was to build on each others' designs by first having one group build in the physical world and one group build in the XR world. Then one person of each group switches to the other group. The newly formed physical group now builds what was made in XR by the previous group and vice versa. The objective was to see if building on ideas only works in XR or that it also works in the physical world.



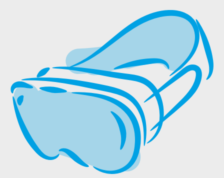
Participants:

Participants were recruited through a newly established contact at KLM and the workshop was organised by the author. For this session no flight attendants were recruited through social media. In this co-creation session, two flight attendants joined, all of them female. All of them had experience on continental and intercontinental flights. Amongst them, they had worked on the entire fleet of aircraft at KLM. As in the first workshop, their extensive experience also led them to mention many of the benefits and disadvantages of working in a galley.

Setting:

The workshop was set up in the same meeting room as Workshop 2. There had been no alterations made to the room since the last workshop.

Fig. 46: The braindump in PIW 3



Preparation and Materials:

The same materials were used as in the second workshop. No alterations were made.

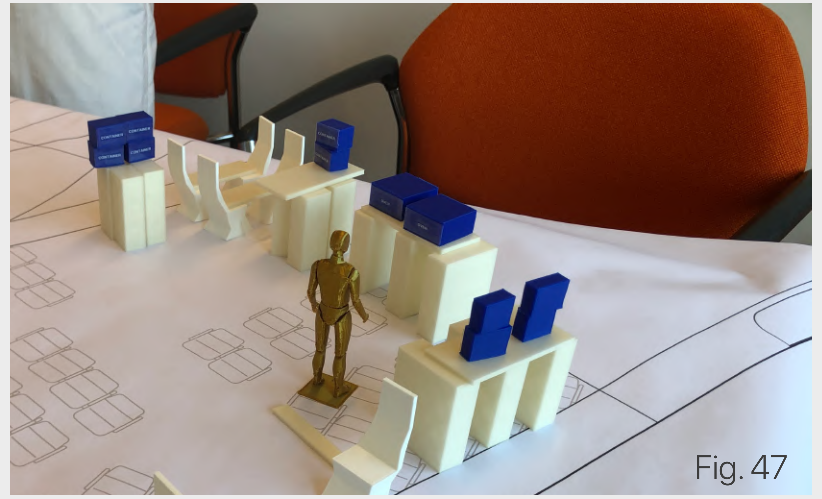
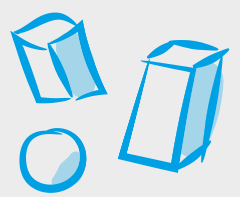


Fig. 47: Building the physical galley.
Fig. 48: Simultaneously building the XR galley



Workshop Structure:

Before starting the workshop the participants were asked for their permission to be on video.
The workshop followed the same steps as the previous workshop. Since there were two flight attendants in this workshop the group was split where one flight attendant joined the facilitator in XR, and the other flight attendant proceeded with designing with the physical blocks.

After creating a galley design in XR and in the physical world the flight attendants presented their work to the facilitator and each other explaining their rationale for the placement of objects and structures.

Due to time constraints the swapping of the two worlds could not be achieved and hence the objective of building onto each other's designs could only be partially met.

In the final part of the workshop the facilitator and the two flight attendants did however immerse themselves in the XR world and together were able to modify and critique the design.

Facilitation and Interaction:

Facilitation conducted in the same way as the previous workshops. However, in the "design the new context" part of the workshop the group was split into two. Here one flight attendant joined the facilitator in XR and the other started building in the physical world. Due to being immersed in XR the facilitator could not aid in the guidance of the flight attendant building in the physical world. However, the facilitator did manage to show the flight attendant in XR how to move objects in the virtual world and gave her one controller to manipulate objects.

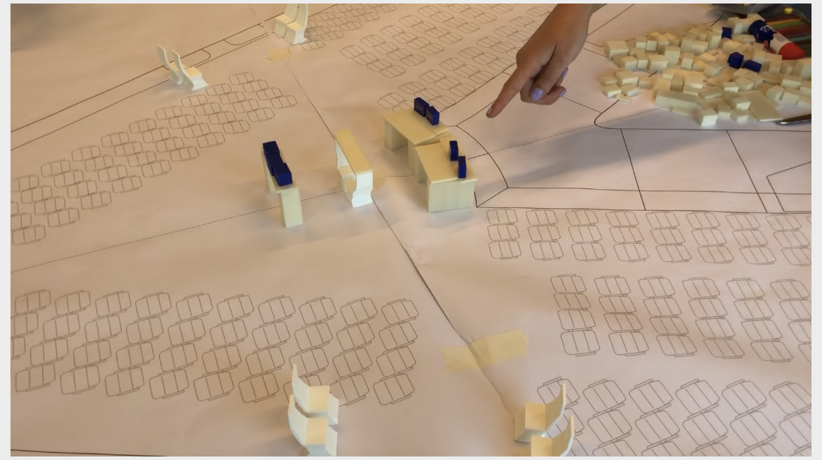
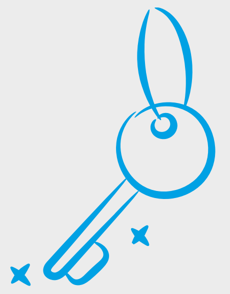


Fig. 49: The flight attendant explaining her design

Observations and Data Collection:

Data was gathered using a Sony Handycam mounted on a tripod in the corner of the room filming the whole session. This video data was then converted into an audio file and underwent the same process as workshop 1.

Fig. 50-51: Impressions of the back galley and the entire aircraft



Key Findings:
The session showed that, firstly more time is needed to test more ambitious ways of using XR and physical blocks. The main objective of the session could not be fulfilled due to time constraints. With the right tools and instructions, flight attendants are able to build their ideal galley layout, but it is also dependent on the participating participants. In the first session, the facilitator was testing out how to make participants create their own galley and hence was also on a journey to discover the right scaffolding to the flight attendants for them to start creating.
Flight attendants, equipped with some instruction, are capable of using XR and manipulating the virtual world.
Because of the small number of participants, more attention could be given to them hence creating the opportunity to show some basic XR tools. It must, however, be said that the flight attendant using XR already had some previous experience using XR.
As with the earlier sessions, immersing in XR was found to add to new ideas and understanding of spatial relations within the flight attendants.

Participants' Feedback:
Quotes mentioned by the participants included:

"If you turn around here, at that other galley."

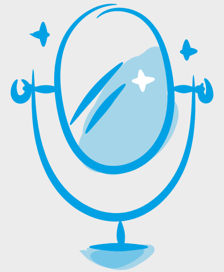
"Then I would align the opening of that galley a bit more with the main path."

"Yes, I really like Anouk's idea, but I'm just for as many passengers as possible."

"Oh, you mean chairs here in the middle where we are standing now?" "Yes, among other things. "

"And then a bar, so keep this galley, but maybe a few more chairs here."

"I would indeed remove this entire galley." "Put the chairs there and then take Anouk's galley design for the back."



Reflection and Analysis:

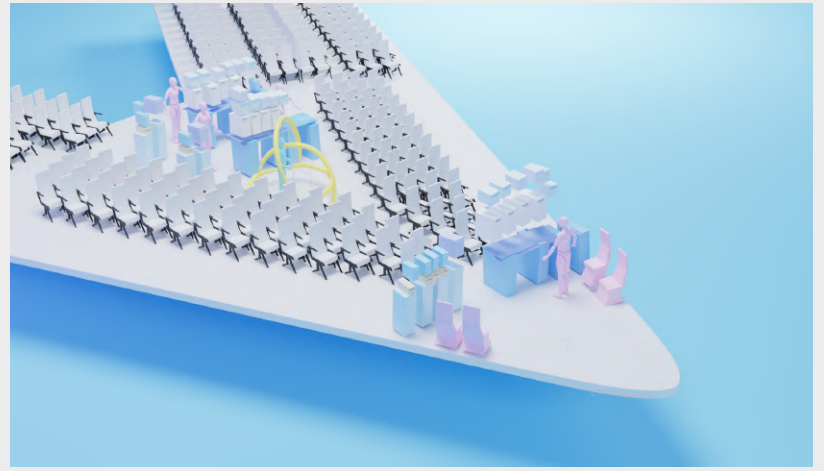
The 1:1 scale sparked a lot discussion between the participants as can be read in the above quotes. The third workshop in the beginning was very similar to the second workshop apart from designing the new context part. Here the group was split and one flight attendant had to do the physical building of the new galley on her own. Because she was building on her own it could be argued this was not really co-creating. The flight attendant together in XR with the facilitator were however co-creating but skipped the physical step. Although the facilitator was experienced in creating in XR, creating with physical blocks did prove to be faster and the flight attendant creating with physical blocks had to wait on the XR group to be done. This could have also been due to the fact that there was more discussion in the XR group because there were more people involved and that the facilitator explained how to use the controller of the headset to let the flight attendant manipulate the XR world.

To keep the headsets from turning off after the facilitator had set up the XR world and placed the headsets on the table before entering the session collaboratively, the facilitator placed some stickers on the headset sensor.

This ensured they did not turn off for at least a few minutes so participants could enter the XR collaborative world together.

The facilitator did not yet find a way to easily align the viewports of each participant quickly before each session.

Fig. 53: A rendering of the galley idea made in XR by the flight attendant and the facilitator.

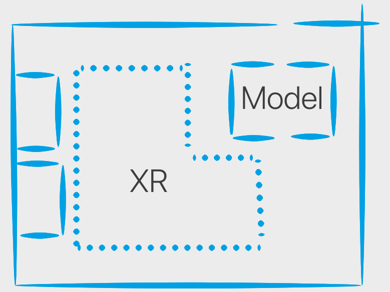


Implications:
The third workshop showed that if a flight attendant had used XR before, the hurdle to use XR was much smaller than flight attendants that had never used the technology before. Also, immersing participants in XR on a 1:1 scale invites discussion and ideas, especially if one of the participants has not contributed to the design that is being viewed on this 1:1 scale. Ideally there would have to be a designer in the XR world and a designer in the physical world guiding participants. Due to the author being the only facilitator & designer in this session it was hard to keep track of what was happening in both 'realities'. Having a designer in both worlds could lead to a more streamlined process.

Summary:
This third workshop indicates that with guidance XR can be used in the same way as the physical model. It must be noted that the flight attendant using this method already had experience with XR which made it easier for her to do so. Some elements of the physical mockup created by the flight attendant using physical blocks were translated into the XR world by the facilitator. These ideas were found to work well by both of the participants when seen on a 1:1 scale in XR. Furthermore, immersing in designs not created by the flight attendants themselves was found to have a positive effect for inviting discussion.

Fig. 54: A top view of the galleys created in XR. In the midsection of the aircraft a yoga or prayer area can be observed in yellow.

5.4 Prototype Iteration Workshop 4



Introduction and Overview

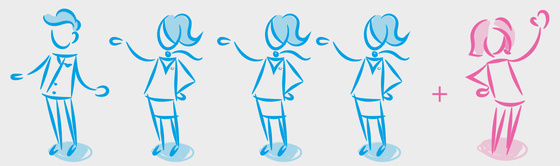
The fourth co-creation workshop was hosted a few weeks after the third workshop in KLM's 107 building. This time taking place in a different office. The first three workshops had taken place in the same rectangular room. The room for the fourth workshop was a square room which was significantly bigger. It is the fourth workshop in a series of five with actual KLM flight attendants. For this workshop, a fellow friend and designer joined the facilitator in aiding and assisting in the workshop.
The author hypothesised that the virtual (XR) world and the physical world should be more aligned to each other to make the transition from both worlds as seamless as possible. The author hypothesised that minimising the differences between both realities would highlight the differences between the two methods more easily.

Objectives:

The fourth workshop had several objectives, the first being to explore whether bringing the physical elements and XR closer in terms of appearance would lead to more easily highlighting the differences between the two techniques. In other words, does minimising the differences between the two realities lead to a better comparison between the physical and the virtual world than without?

The second objective was to see if more guidance based on creative facilitation methods would lead to better overall design results the flight attendants would be more satisfied with.

The third objective was to get participants to design their ideal galley and present it to each other instead of presenting it to the design facilitators. The author hypothesised that presenting work to each other would spark ideas and discussion, leading to more desirable results in the end.



Participants:

Participants were recruited by means of a flyer made by the author that was spread amongst KLM cabin crew members internally at KLM. In this co-creation session, four flight attendants joined, three female and one male. All of them had experience on continental and intercontinental flights. Amongst them, they had worked on the entire fleet of aircraft at KLM. For this session an additional facilitator also joined.

Setting:

The workshop took place in a meeting room in the same building as the previous workshops. This room was significantly larger than the previous rooms and provided a lot of natural light, wall space and a whiteboard. The larger surface area of the room made it possible for participants to move around more freely and to set up more materials.

Fig. 54: The new (larger) room for PIW 4

Preparation and Materials:

The same materials were used as in the second workshop. No alterations were made.

- Additional Post-Its in more than six different colours.
- Additional A4 and A3 paper.
- Large sheets of A0 paper for the 'brainwriting stage'.
- Posters of the Flying-V for reference.
- Three extra Meta Quest 2 HMDs with Gravity Sketch installed. A total number of seven headsets were brought to the workshop.
- A total of eight Gravity Sketch licences with access to the TU DELFT EDU environment.
- A Floorplan of the Flying-V 1:20 scale with a lower opacity (more greyed-out) seat plan for extra reference and a better understanding of a potential cabin layout. This subtle seating plan was barely visible and served as a guide.
- 2X extra 1:20 scale 3D-printed mannequins of flight attendants with an average converted height of a Dutch female aged 20-60 years old of 1668 mm. And a mannequin with an average converted height of a Dutch male aged 20-60 years old of 1817 mm. Both are modelled in Gravity Sketch and Blender.
- 392X 1:20 scale redesigned low poly 3D-printed chairs modelled in Blender and 3D-printed on eight Ultimaker 2+ models.
- 2X13 + 2X6 parts of the Flying-V fuselage adapted from Lisa Wamelinks' (Wamelink, 2021) Blender model split into 32 parts 3D-printed on six Ultimaker 2+ models and one Ultimaker S5 model.
- Additional galley building blocks 3D-printed on a combination of Prusa Mini and Ultimaker printers.

Fig. 55

Fig. 55: The facilitator laying out the newly designed physical model

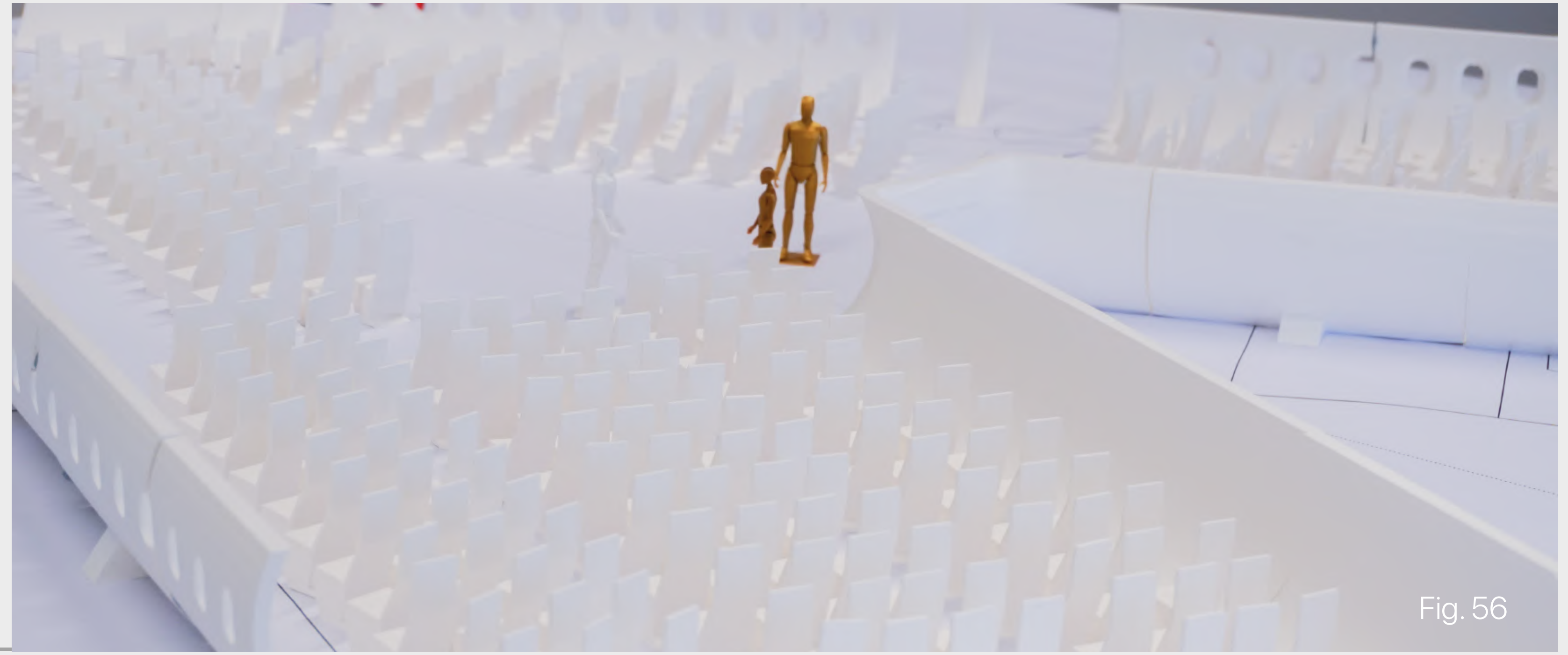


Fig. 56

Fig. 56: A close up of the new model

Workshop Structure:
The workshop was set up differently than the previous workshops. Because of the largest amount of participants to date, and the availability of another facilitator, more possibilities could be explored.

The first third of the workshop followed a similar workflow to the previous workshops. However to make this part more engaging and useful to the participants in the later stages of the workshop a brainwriting approach was chosen. Participants were asked to write down on a particular colour Post-It anything that came to mind when thinking of an aircraft galley. In previous workshops they were asked to only think of good and bad things about a galley, the extra general step left room for thought not necessarily related to good and bad adding depth in the next stages of the brainwriting.

In the previous workshops, participants took turns reading out their Post-It's, and the facilitator was the one making clusters and discussing with the flight attendants. In this workshop, all of the Post-It's generated by the flight attendants were gathered on a big table. Participants were invited to stand around the table and pick up Post-It's that struck their attention and read them out. They were encouraged to place them on the wall in front of them. Clusters with certain themes emerged. This clustering happened naturally whilst participants gathered around the wall.

Several clusters emerged, and participants were asked to confer with one another and discuss which cluster they deemed the most important regarding galleys. A top two of clusters emerged and from this top two, design "how might we" questions were formulated by the facilitators. These were then used as input for the following stage 'Design the new context.

After the break, the participants were exposed to videos of the Flying-V and videos of innovative galley designs to spark their imagination. Once the videos had been shown, the participants were reminded of the clusters they had made before the break. They were presented with the design questions formulated by the facilitators during the break. They were asked to keep these design questions in mind whilst designing. The group was then split into two, where two flight attendants joined a facilitator designing their galley on a 1:20 scale physical model, and the other two flight attendants joined a facilitator designing their galley on a 1:20 scale virtual model in XR. The participants were tasked to present their final designs to each other after the exercise.

Whilst designing, the facilitators asked questions to probe the participants and asked why they made specific choices. After creating their work, both groups were invited to present their work to each other. The physical group presented to the virtual group first. Because of two headset failures, one member of the virtual group presented to the members of the physical group whilst being immersed in XR on a 1:20 scale with one facilitator also immersed.

After this, the facilitator scaled up the model to a 1:1 scale and invited one participant at a time to explore the model created by the virtual group.

Fig. 57: The brainwriting stage

Fig. 58: All participants writing down things they dislike about a galley after previously being instructed to right positive and general things that came to mind.

Fig. 59: All participants and the facilitator clustering the things that came to mind during the brainwriting.

Facilitation and Interaction:
As opposed to the previous workshops, this workshop was facilitated by two designers. The author was the main facilitator and led the full session, whilst a fellow friend designer led parts of the workshop. This proved to be of great benefit to the main facilitator and the session as a whole. The fellow designer could take a step back and analyse the session while providing tips and insights that could be directly fed into the session.

An extra benefit of having two designers instead of one was allocating tasks that could be spread out over the two designers. The group could also be split in half, each having a designer lead them, making for a more efficient workflow.

The designers could step into their designer role by leading parts of the session but could also empathise with the participants and join them and guide them in their creation role. More questions about why certain choices were made could be asked, facilitating discussions and solidifying design choices.

This workshop also introduced the concept of the 'idea sheet' as suggested by the fellow facilitator. This idea sheet served as a platform to remember ideas that the participants considered to be good or great ideas. The sheet was an empty A4 paper with room for sticking on Post-It's with these ideas.

Interaction between the participants was natural and did not have to be stimulated at all. All participants got along as if they had been working together for years. This could be due to the fact that flight attendants do not know who they get to work with until the day of working and are used to these conditions, albeit it being a design assignment.

Fig. 60: The second facilitator writing down and keeping track of the 'great ideas' thought up by the flight attendants.

Fig. 61: The flight attendants and second facilitator building the galley in the center of the aircraft.

Observations and Data Collection:
Data was gathered using a Sony Handycam mounted on a tripod in the corner of the room, filming the whole session. The fellow designer could take additional videos, photos and notes during the session. These were bundled in a PDF on her iPad. After the session, a questionnaire was handed out to the participants. This questionnaire contained but was not limited to questions about spatial, imaginative and creative aspects of the techniques used.

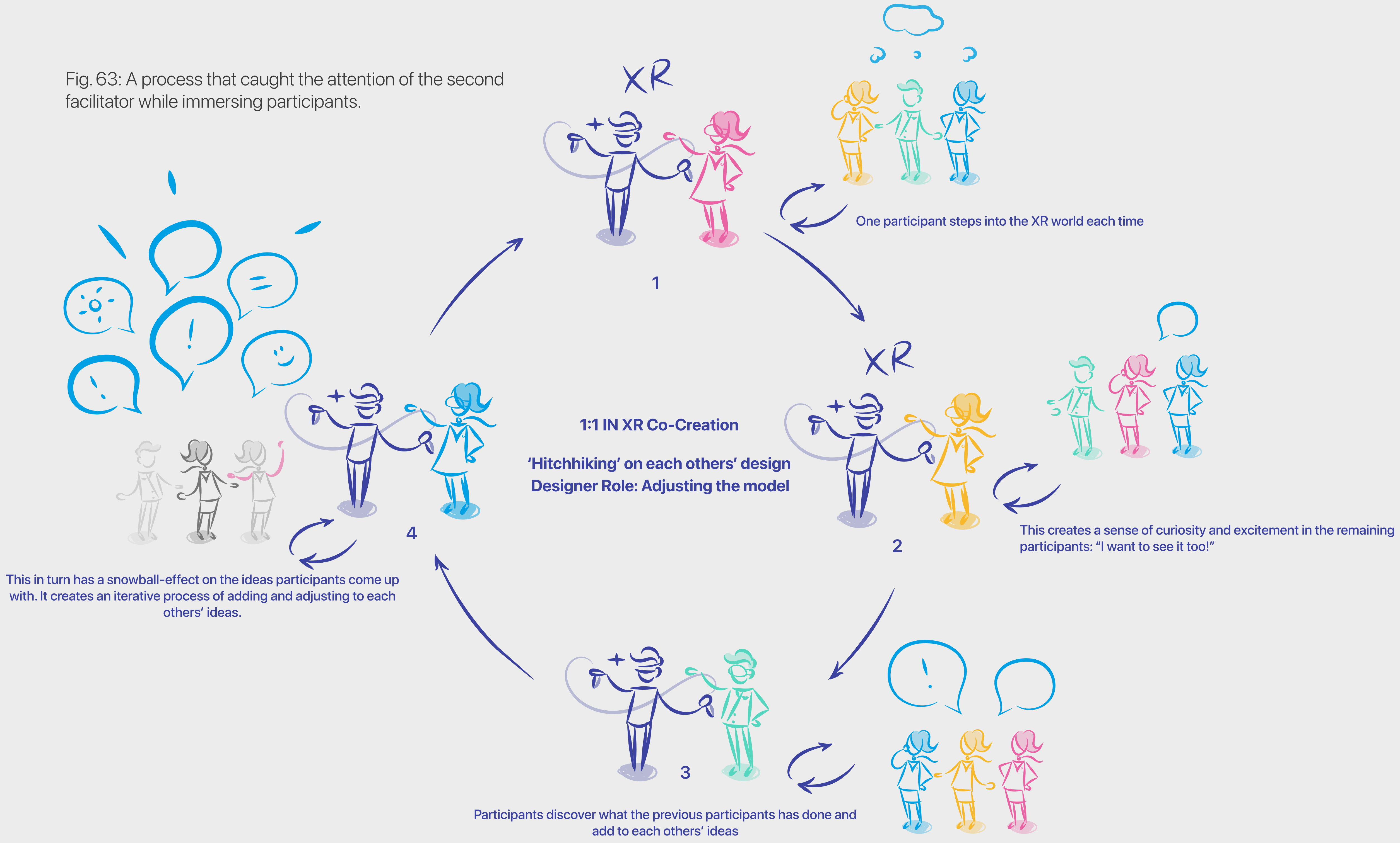
Fig. 62: Result of the clustering and brainwriting stage

Key Findings:
It was found that the brainwriting technique is more effective than just brainstorming about the positive and negative aspects of a galley. The democratic process of deciding which clusters to explore further helped create a team feeling between participants because they agreed on tackling the same problem. They felt they had ownership over the ideas they had created, and this resulted in good communication between the participants because they were attempting to solve the same problem.
This was facilitated by the 'how might we questions' that were kept in the back of the heads of the participants when designing.

The immersion on a 1:1 scale proved to have to most impact on the participants. After the virtual design was made on a 1:20 scale, the facilitator scaled the model to 1:1. The facilitator stayed in XR while one participant at a time explored the design at full scale. In this part of the session, participants started to hitchhike on each others' designs. The first participant provided feedback on the existing design, and the facilitator immediately gave feedback in XR. The second participant could then provide her feedback, and the design kept on evolving by rotating the participants in XR. This meant the participants could add to each others' ideas in XR.

Something only done with the physical blocks first. Because the other participants had created the initial design but could not see what additional changes were made to the model, it created a sense of excitement in participants as they were eager to see what alterations were made to their initial design. The designer could act as the intermediary between the participants and the model by changing the model while the participants did not have to worry about technical aspects. The anticipation to see what others had created led to a lot of positive emotion in the participants making them create even more ideas.

Fig. 63: A process that caught the attention of the second facilitator while immersing participants.



Reflection and Analysis:
The fourth co-creation workshop hosted at KLM succeeded in accomplishing the main objectives. The facilitators made substantial adjustments to the structure, facilitation, and engagement methods from the previous sessions, which yielded fruitful outcomes.

The physical and virtual models were made to look alike as much as possible. This resulted in participants not being as surprised or overwhelmed by the number of chairs/ passengers as in earlier workshops when presented with the virtual model after seeing the physical model. Making them focus more on the task at hand instead of being intimidated by the number of passengers. 'Good' ideas, according to the participants, were collected on the idea sheet. The physical group had more ideas on their sheets than the XR group. Eleven ideas compared to four ideas, respectively. It is uncertain if the reason for this could have been the switch of medium for the XR group or the lack of ideas compared to the physical group.
Flight attendants seemed happy with their design results and had a stronger sense of ownership of their creations than their colleagues in the previous workshops. This was exemplified in the 1:1 immersion stage, where the creators of the initial design were worried but also excited to see their fellow participants alter their initial designs. Presenting ideas to each other resulted in questions being asked between the participants and expanding on ideas.

Regarding the logistics and setting, the change in location and room size impacted the group dynamics positively, offering more space to move around and interact with materials and creating a more conducive environment for creativity by using the walls to write on and the tables for the model. The introduction of an additional facilitator also provided more opportunities for interaction and discussion, creating a more vibrant, engaging, and efficient atmosphere.

The workshop was designed to create situations where the realities could be compared and analysed. By having the participants design and present in both mediums, the facilitators could see what worked well and what could be changed. The 1:1 scale sparked the most excitement and engagement among the participants. Since there was a build-up to this stage, it is unclear if this would be the same in case of directly starting on a 1:1 scale.

The brainwriting technique was a standout in the workshop structure, as it facilitated more democratic participation and created a shared sense of ownership among participants, which likely influenced their engagement and satisfaction levels positively. Participant recruitment was effective, resulting in a diverse group of flight attendants with various experience levels, contributing to a wide range of perspectives. Their natural and seamless interaction can likely be attributed to their professional backgrounds, where they are accustomed to working with different colleagues.

The experience of exploring the design at a full-scale 1:1 model in the XR environment has been particularly impactful, enabling continuous feedback and evolution of the design and fostering creativity and positive engagement among the participants.

Overall the workshop was well received by participants and fostered a cooperative and engaging environment, as seen in the questionnaire results completed by them. Given the importance of the XR experience in the workshop, ensuring all headsets function correctly should be a priority and a dedicated person making sure the HMDs work properly would be of great help. Also, backup equipment may be necessary to avoid interruptions or technical issues.

Implications:
Integrating Extended Reality (XR) and 'make tools' provides a comprehensive understanding of the design space in the co-creation process of the Flying-V's interior. It emerged from the workshop that the immersive quality of XR and the tactile nature of the 'make tools' allowed participants to visualise, iterate, and refine their designs effectively. Multiple benefits were observed, including enhanced collaboration, increased creativity, and an enriched understanding of the design context. By using 'make tools' within an XR environment, participants could quickly adapt and adjust their designs based on feedback and personal insights. An increase in engagement and creativity was observed by the facilitators, especially towards the end of the workshop, which likely had a positive effect on the final design outcomes.

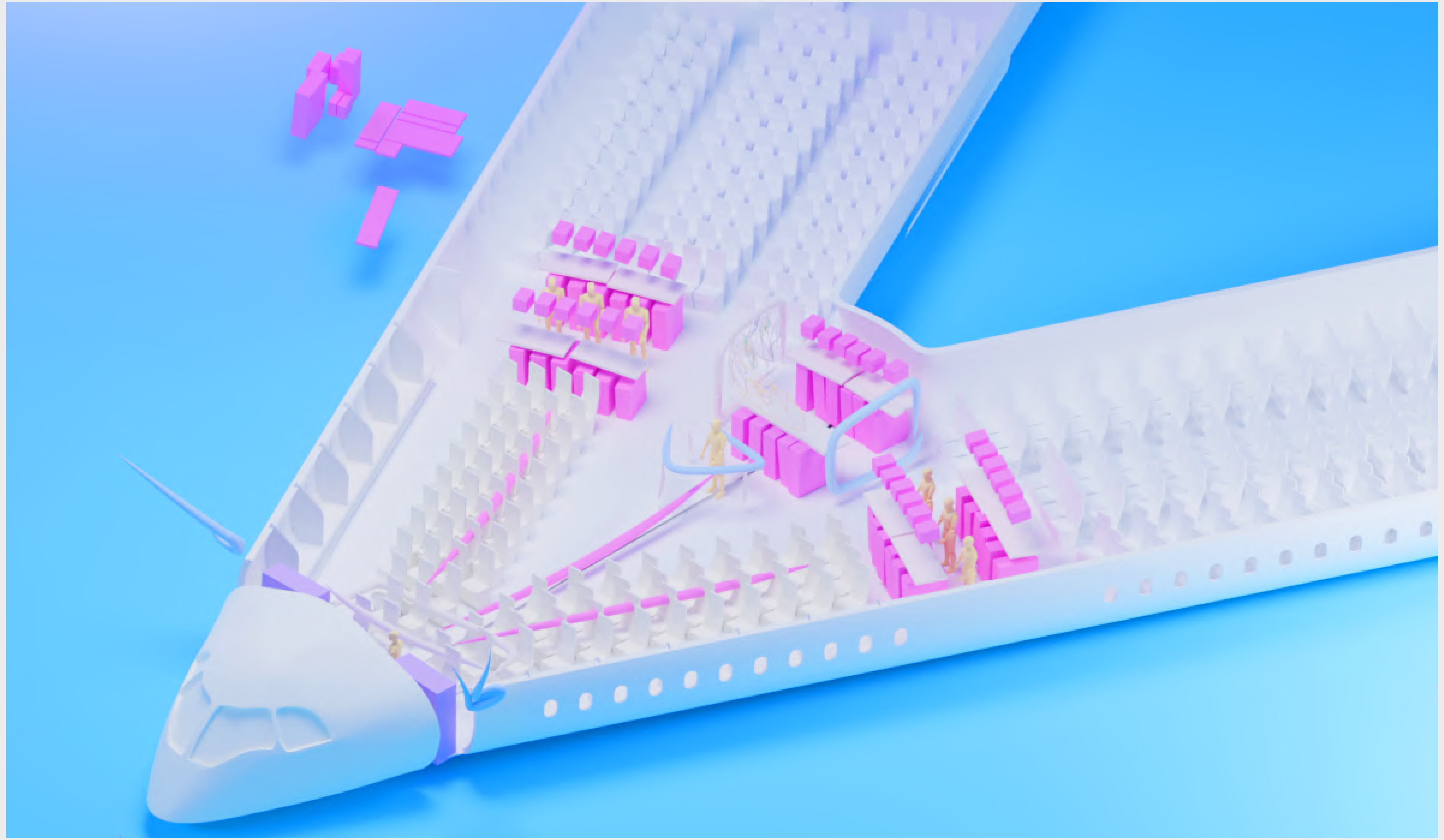


Fig. 64: A rendering of the of the galley design results from PIW 4 after 'hitchhiking' on each others' designs.

Summary:
The fourth co-creation workshop was conducted at KLM with four experienced flight attendants, aiming to investigate whether minimising the differences between physical and virtual realities would make their comparison more effective. The second objective was to see if better design results could be obtained with more creative facilitation guidance. Finally, the facilitators encouraged participants to design their ideal galley and present it to each other to stimulate discussion and idea generation.
The workshop setting was a large, square room with plenty of natural light, wall space, and a whiteboard. A diverse range of materials was used, including various post-its, large paper sheets, posters, headsets, 3D printed objects, and more.
The workshop structure was altered from previous iterations, allowing participants more agency in clustering and selecting themes. The facilitation was split between two designers, allowing a smoother workflow and better participant interaction. Data collection was done via a mounted camera and additional notes were made by the fellow design faciliator.
Key findings from the workshop included the effectiveness of the brainwriting technique and the impact of 1:1 scale immersion in the virtual design. Participants showed positive engagement, offering feedback and continuous improvements to the design. The collected 'good' ideas were of greater number in the physical model group than in the XR group. However, the reason for this remains unclear.
Participants seemed pleased with their designs and displayed a strong sense of ownership. The new location, larger room, and additional facilitator provided a more conducive environment for creativity and interaction. The workshop was well-received by participants. Technical difficulties with the headset were noted as an area for improvement.

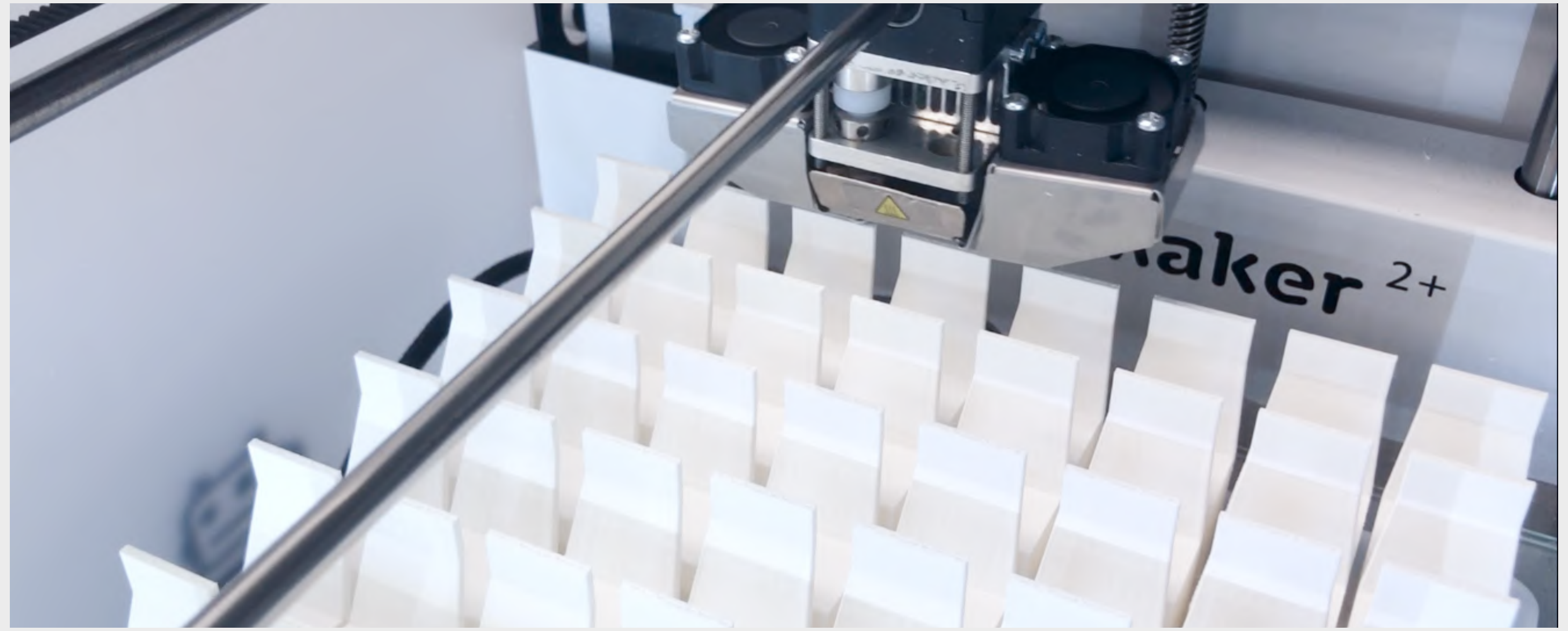


Fig. 65: 3D printing of the chairs for the new model. A total of more than 422 chairs were printed (excluding failed prints)

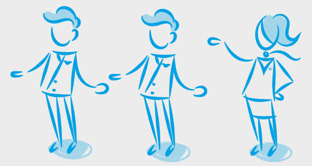
Fig. 66: Practising the building of the model prior to the workshop

Fig. 67: The model being used in PIW 4 with the more efficient 3D printable chair design and extra printed galley elements

5.5 Prototype Iteration Workshop 5

Introduction and Overview:
The fifth co-creation workshop was hosted on the same day as the fourth workshop in the same room. One facilitator led this workshop. In this workshop, no XR was used, and participants only interacted with the physical model. The author hypothesised that showing only the physical model would lead to fewer ideas than showing the model in XR.

Objectives:
The primary objective of this workshop was to examine the impact of this hands-on design approach on the final design results. To explore whether more guidance based on creative facilitation methods would enhance overall design results compared to previous workshops that were not implemented in the physical phase.



Participants:
Participants were recruited by the same means as the fourth workshop. In this session, three flight attendants joined one female two male.All of them had experience on continental and intercontinental flights. Amongst them, they had worked on the entire fleet of aircraft at KLM.

Setting:
The workshop took place in the same room as the previous workshop.

Preparation and Materials:
The same materials were needed as in the previous workshops, with the exception of the XR equipment.

Workshop Structure:
Due to logistical problems, the workshop started 25 minutes later than expected.

The first third of the workshop followed a similar workflow to the previous workshops. As with the fourth workshop, the brainwriting approach was chosen and followed the same structure as the fourth workshop by making clusters and labelling the most important ones.

From these clusters, two design questions emerged:

1. "How can you create a galley that is super ergonomic?"
2. "How can you make the workability as pleasant as possible?"

After the break, the workshop followed the same steps as in the previous workshop, and participants were asked to keep the design questions in mind whilst designing.
The group was then guided to the table with the Flying-V physical model and instructed to design their galley based on the questions they had formulated.
After creating their work, the flight attendants presented their ideas they had mutually agreed on to the facilitator.

Facilitation and Interaction:
This workshop was led by one facilitator, as opposed to the previous workshop, where two facilitators were present. It became apparent to the facilitator that having another design facilitator present greatly improves efficiency and engagement levels in the workshop. An additional facilitator also enhances the process by being able to take a step back to observe the main facilitator and intervene when necessary.

For this session, the facilitator directly used the successful techniques from workshop four and implemented them into this one. These included the brainwriting stage, the selection of clusters and the formulating of design questions.

Once the first third of the workshop was done, the facilitator explained the exercise and told participants they would work with the physical model. The existence of XR was not mentioned. The concept of the idea sheet was also introduced to the participants. The facilitator stepped in to write down any great ideas, as the participants did not do this.

Interaction between the participants was natural and did not have to be stimulated at all. Interaction between participants was very much focused on being service minded and thinking about logistics instead of sparking out-of-the-box ideas. However, this pragmatic approach led to other interesting outcomes of where galleys would have to be placed and what they would look like.

Fig. 68: The model being used in PIW 5. Post-Its also became part of the building materials

Observations and Data Collection:
Due to the memory card being full, data could not be collected using the Sony Handicam. The facilitator himself had to take notes by hand. After the session, a questionnaire was handed to the participants with questions about the session. The questions about XR being had been crossed out since only the physical model was used.

Key Findings:
As expected by the author, the blocks were very easy to use, and participants rated the efficiency of the blocks very high. Considering the whole session, participants reported they were the most engaged during the building with the blocks.

As with the last workshop, it was found that the brainwriting technique effectively provided scaffolds for the participants to make their designs. This collaborative effort of designing their own galley sparked excitement and a willingness to work on their own galley design. Participants felt they could express their concepts and ideas effectively using the physical blocks.

Participants' Feedback:
Quotes mentioned by the participants included:

"I think this is quite workable, a lot of galley surface."
"What if you place some drink stations here to tap cold water? That saves a lot of plastic bottles."
"This is so nice, I really like it. I completely want to work in it."
"Can't we fit the cradles here in the curvature, so you have 35 babies in a row?"

Fig. 69: The model being used in PIW 5

Reflection and Analysis:
The fifth co-creation workshop offers an exploration into the effects of hands-on design, as opposed to the previous workshops, where extended reality (XR) is combined with physical. This change was undertaken with the author's hypothesis that this shift might lead to fewer ideas, suggesting a perception that physical models might not unlock the full range of creativity.

Material-wise, an empty memory card for the camera would've been desirable since no video records could be made. Participants had questions on how the aircraft would be supplied by catering and where all the doors were. A more complete aircraft model for a strictly physical workshop might be desirable, including indicating the aircraft's height.

The group had a similar amount of 'good ideas' as the virtual group from the fourth session; just like in the fourth session, participants were excited about their designs and eager to work in them.

The participants started to create with a strong sense of pragmatism, counting the number of passengers and corresponding flight attendants needed to complete the job. From this approach, an idea of a fountain station arose. This would ensure passengers could get their own drink and would save the flight attendants a service round. Furthermore, many plastic bottles could be saved if passengers can provide themselves with drinks.

A so-called service wall was made in the back parts of the aircraft. Here drinks and snacks would be available to passengers in a way that prevented them from falling out or leaving doors open during turbulence. A vending machine kind of idea where participants could also gather around a standing table. These ideas arose whilst thinking of how to make the service more efficient.

The facilitator could have maybe stimulated more out-of-the-box thinking at the beginning of the project. However, novel ideas eventually surfaced after playing with the model long enough. There were also some moments of distractions in the workshop when talking about work. These did not entirely derail the workshop but hindered the continuation of the workshop at some points.

Fig. 70: The central galley as designed by the flight attendants in PIW 5. Post-Its indicating walls

Implications:
The physical model was successfully used by the flight attendants. They had fewer "good ideas" than the physical group from the first workshop and around the same amount as the XR participants from the previous workshop. Regarding ideas generated, a hands-on model can be just as effective or even more effective in producing a certain amount of ideas than an XR model on the same 1:20 scale. Future workshops should, therefore, not discount the value of physical models.

The pragmatic approach employed by the participants focuses on service, efficiency, and practical solutions, implying that the background of the participants plays a significant role in shaping the design outcomes and highlighting the importance of carefully selecting participants.

From a facilitation standpoint, future workshops should ideally be facilitated by more than one person to improve efficiency and to make it easier to stimulate out-of-the-box thinking.

Summary:
The fifth co-creation workshop was conducted without Extended Reality (XR) and involved physical models only. Three experienced flight attendants participated and created design ideas based on brainstorming clusters. The facilitator noticed that having another design facilitator could improve efficiency and engagement levels. Key findings revealed the physical blocks were highly efficient and engaging for the participants, leading to a galley design all flight attendants would be happy to work in. The number of "good ideas" produced was comparable to previous sessions in XR, but less than the previous session using the physical mode. Participants demonstrated pragmatism, focusing on service efficiency.

Fig. 71: An impression of the first layout in PIW 4

Workshop Findings

6

6.1 Identified Criteria

This chapter will discuss the results from the various PIWs, focusing on how Extended Reality (XR) and physical 'make tools' can synergise in the co-creation process. Besides data gathered through audio recordings, observations and notes taken during the PIWs, questionnaires were completed by flight attendants post-workshop participation. This served as an additional data source for evaluating the prototype's effectiveness. The questionnaire comprises various evaluation categories or criteria, which will be explained in the following sections.

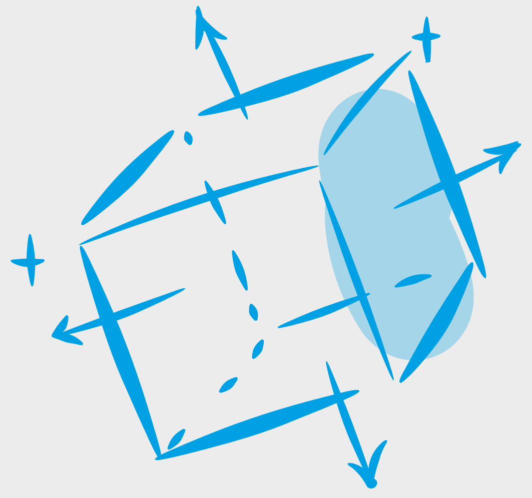
Stadler (2021) proposes a set of criteria for evaluating XR experiences, including Safety, Validity, Time & Cost, Variability, Interaction, Immersion & Effort.

For the purpose of this thesis and the unique intersection of co-creation and XR, other criteria are deemed more important by the author. These are:

- Spatial Understanding
- Imagination Stimulation
- Engagement Level
- Collaboration
- Learning Curve
- Efficiency
- Realism
- Transferability

These criteria are largely informed by insights gained from the initial PIWs hosted by the author. They can, in some sense, be seen as subcategories of the three pillars laid out by Santosh (2022), that contribute to the collaborative development of new value within co-creation and XR. These pillars are defined as: Collaboration, Interaction and User Experience. Within this framework, Collaboration focuses on how and where to collaborate, Interaction focuses on how to collaborate, and User Experience on what will be collaborated on.
Santhosh (2022) also states: "The power of co-creation lies in how well the users are collaborating and interacting in the environment. Development of such co-creative platform or environment which is capable of accomplishing the three key elements of co-creation has been unprecedented - in the realm of XR- and has not been given much of importance."
The author of this thesis proposes the elements of physical 'make tools' to be a stepping stone to a more creative and efficient use of XR in co-creation.

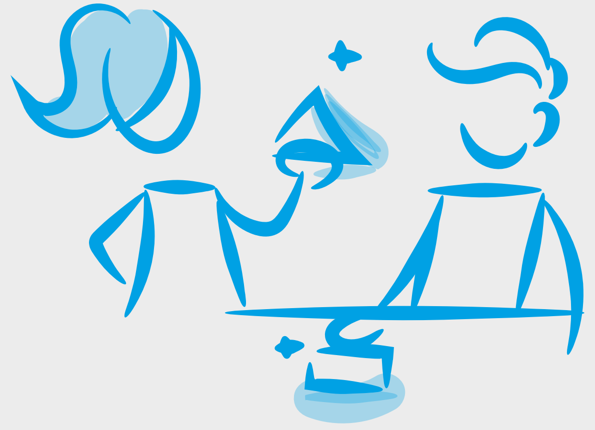
The following section will provide a detailed explanation of each of the criteria mentioned earlier. The criteria not only apply to XR but also to the physical objects being used in the workshop.



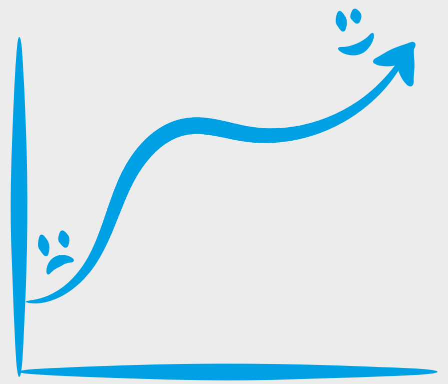
Spatial Understanding:
According to Krokos (2019): "Virtual reality displays, such as head-mounted displays (HMD), afford us a superior spatial awareness by leveraging our vestibular and proprioceptive senses, as compared to traditional desktop displays" Because of this, the first category of the questionnaire is labelled "Spatial Understanding". The questions in this category target the difference between the physical blocks and XR.
Evaluating spatial understanding will help measure whether participants are able to comprehend the physical constraints of the Flying-V aircraft.

Imagination Stimulation:
This speaks to the ability of the workshop to inspire creativity in the participants. A design workshop for the galley of the Flying-V should not just involve understanding the physical space. It should also encourage participants to come up with new and innovative ideas. XR can support: "users' imagination and experience of new worlds that are different from the ones they are accustomed to"(Chirico, 2023). Using physical blocks and immersive XR technology may help with this by providing different ways to visualise and experiment with galley designs. When talking about Lego Gauntlett (2015) mentions: "Harnessing the power of people working together on a shared enterprise is ultimately more valuable than well-informed, imaginative individuals doing clever things."

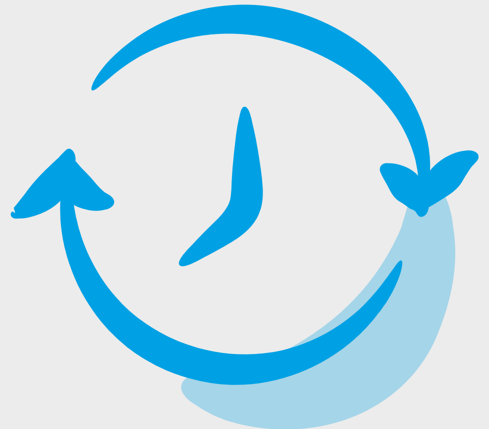
Engagement Level:
As stated by Sanders & Stappers in Convivial Toolbox (2012):" Participatory design is an approach to design that attempts to actively involve the people who are being served through design in the process to help ensure that the designed product/service meets their needs." The involvement or engagement level of participants is hence crucial for a successful project outcome. The level of engagement refers to the degree to which participants actively participate in the workshop. High engagement levels typically indicate a workshop that is well-facilitated and interesting to participants. Techniques such as the use of physical blocks and XR may help to increase engagement by providing hands-on, interactive elements and immersive virtual worlds. Gauntlett (2014) also mentions that (Lego) building helps shift people's sense in the world from being a consumer to being a creator, contributing to creative ownership and engagement with the environment.



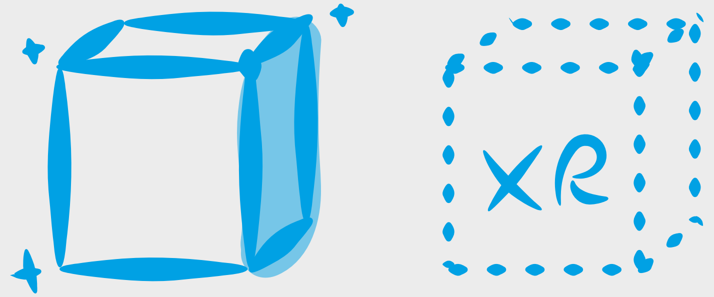
Collaboration:
As stated earlier by Santhosh (2022), the power of co-creation lies in how well participants collaborate. As previously discussed in this thesis, we are facing an increase in the complexity of problems that demand collaborative and creative solutions (Sanders & Stappers, 2012). In the context of designing an environment like an aircraft galley, which inherently requires collaboration, it stands to reason that the design process should be similarly collaborative, and if and how physical objects and/or XR aid in this collaboration.



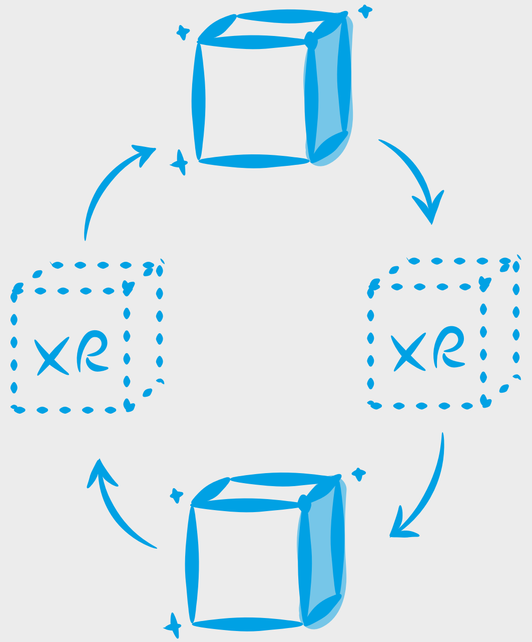
Learning Curve:
This refers to how quickly participants are able to pick up and understand the tools and concepts being used in the workshop. A learning curve that is too steep may leave participants feeling frustrated and disengaged. From personal communication with staff from the XR zone in Delft, it became apparent that using XR, especially with first-time users, could be a challenge.



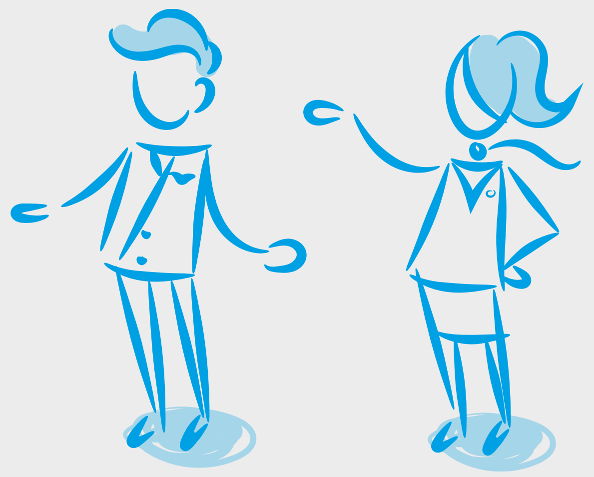
Efficiency:
This relates to participants' capacity to accomplish tasks within the allocated time. The comparative efficiency of using physical blocks versus Extended Reality (XR) offers an intriguing perspective. It is essential to identify which method is more effective (if any) and how this potentially influences the overall outcome of the workshop.



Realism:
This section explores the aspect of 'Realism' within the Extended Reality (XR) environment. This measures the degree to which the XR setup emulates a real-world or envisioned galley for the Flying-V accurately. The focus is not only on the perceived authenticity of the XR environment but also on how effectively virtual designs can be linked to real-world applications. This section also aims to identify if the XR environment aids in anticipating practical issues that might not be discernible with physical blocks and vice versa.



Transferability
This section investigates 'Transferability' in relation to the shift in medium from physical blocks to Extended Reality (XR) and vice versa. The aim is to understand how much this change in medium contributed to generating new insights and if any challenges arose during this shift.



Results Questionnaire
A total of n=15 flight attendants joined the PIWs, with every PIW averaging 3 participants. The questionnaire was formulated after the 3rd PIW based on previous workshop insights. Hence of the 15 participants, n=10 participants were able to fill out the questionnaire.
n=7 experienced both XR and physical models, while n=3 only experienced the physical model.

The results of these two groups will be shown separately.


Fig. 72


Fig. 73


Fig. 74

Fig. 72-74: An impression of the facilitator being immersed in the different PIWs

6.2 Results from the Prototype Iteration Workshops

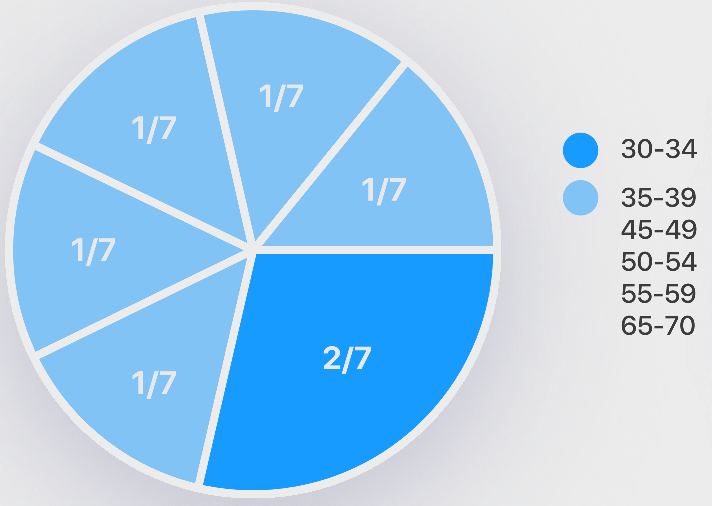
Interpretation of Results
First, the data from the workshop will be presented in a condensed form and interpreted. Following that, answers will be provided for each research question stated earlier based on the inquiries made in the questionnaire.

The groups that have both used Extended Reality (XR) and physical objects (Ph) will be referred to as the XR+Ph group.

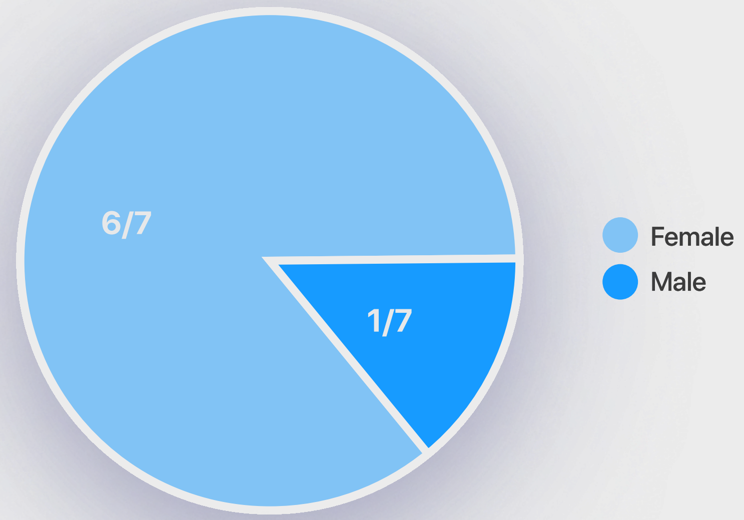
The group that has only used physical objects (Ph) will be referred to as the Ph group

XR+Ph Group

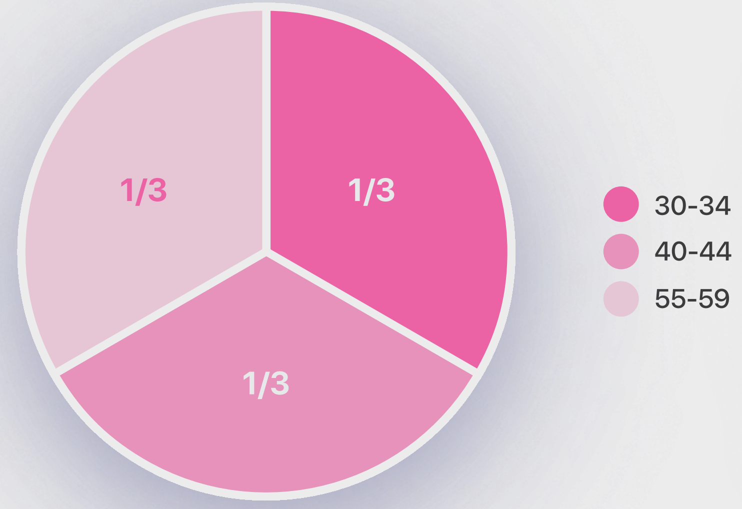
Ph Group



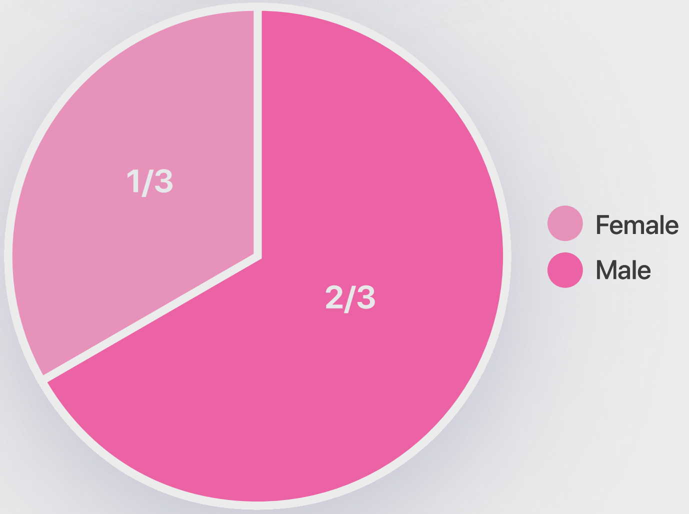
In the XR+Ph group a large variety of ages was represented in the workshops. The largest group being 30-34 years old.



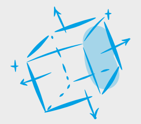
As can be seen in the chart, the majority of the flight attendants in the XR+Ph groups were female.



In the Ph group, there was an equal distribution of ages ranging from 30 to 60.



The Ph group consisted of one female and two males.



Spatial Understanding

9.1

On average, the XR+Ph group gave a rating of 9.1/10 for their ability to perceive and reason about space using XR in comparison to using physical blocks. Every participant reported that XR aided in visualising the design more effectively than using physical blocks. The primary reason cited for this was the spatial capabilities of the XR technology

7.8 7.6

Confidence in their spatial design using physical blocks as rated by both groups. Two responses were discarded since these participants did not engage with the physical blocks in the workshop.

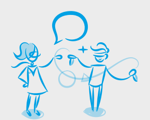
Imagination Stimulation

8.9

Participants rated the stimulation of creative thought with XR with an average of 8.9/10. During observation of session four, it was noted that numerous innovative ideas emerged during the experiment and design phase with the physical model. However, questionnaire responses indicate that participants recall innovative ideas surfacing exclusively while using XR.

Based on the responses, it appears that using physical blocks during the session stimulated the participants' imagination, leading to several innovative ideas. These ideas include a self-service snack/drinks station, a galley design accessible from different sides of the cabin, and self-service stations for passengers featuring soda and water fountains.

Participants reported feeling more creatively free using XR largely because of the immersion into the virtual world.



Engagement Level

9.4 9.6

Overall engagement for the session as a whole was rated as above

Engagement levels varied from when the post-its were used to brainstorm to watching the movies edited by the facilitator to using XR.

It appears that the act of physically building or manipulating elements in the model was a key point of engagement for the participants. All three respondents highlighted moments of constructing galleys or working with the blocks as times when they felt mainly engaged. This contrasts the group that used both mediums as they mentioned XR made them feel most engaged.

The responses suggest varied experiences and preferences among the participants when comparing their levels of involvement or absorption while using XR versus physical blocks

Collaboration

8.7 9

Considering the whole session, participants rated the teamwork of the session as above.

The respondents have diverse perspectives on how using physical blocks influenced their team's collaboration. Ranging from helping the collaboration to complementing XR.

All participants felt like the physical blocks helped their collaboration.

The majority of participants felt that using XR did not impact their communication with team members, implying effective communication within the XR environment. However, one issue identified was the lack of awareness regarding each other's precise location, which sometimes led to minor collisions when participants were standing in close proximity.

Learning Curve

7.9

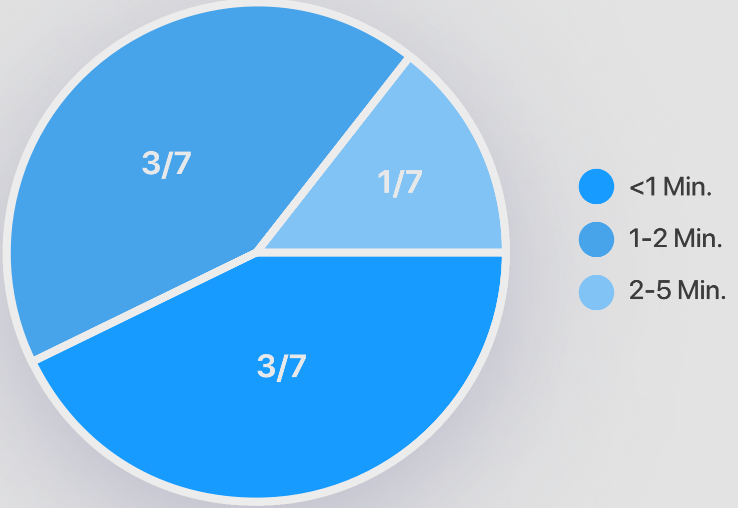
The ease of use for the XR technology was given an average rating of 7.9 out of 10. This may be attributed to the facilitator handling all the technical aspects of XR, thereby reducing the cognitive load on participants associated with learning new technology.

8.8 9

The ease of use for the blocks was rated higher at 8.8 out of 10, compared to XR. This higher rating could suggest that participants found working with blocks more intuitive or familiar, although further analysis or additional data may be necessary to confirm this. Two participants were excluded from the data again.

The ease of use for the blocks was rated at 9 out of 10. This is higher than the group that used both methods.

Every participant indicated that they could convey their ideas using both physical blocks and XR effectively. While some highlighted the difficulty of representing objects 'hanging' or placed in the air when using blocks, making certain designs more complex, it was also noted that these blocks simplified the process of explaining their intentions.



Most people got comfortable with XR within around 2 minutes.

Efficiency

Responses suggest a general inclination towards favouring XR for speed, but the perception varies, likely due to individual comfort levels and interpretations of the task.

In summary, all three participants seemed to appreciate the efficiency and tactile nature of physical blocks in completing their designs, indicating they were effective tools for this task.

8.9

The efficiency of XR in aiding the ideation and prototyping process was rated as above

7.8 9

The physical group rated the efficiency of using blocks as a 9/10. This higher rating could be due to the lack of comparative experience with XR in this group. Nevertheless, it strongly suggests that using physical blocks is an effective method for layout design, specifically in this case for the interior of the Flying-V.

Realism

8.4

Participants rated the realism and the XR environment representing a real galley with an 8.4/10. This was surprising to the facilitator since the representation of the galley in XR was very low poly and low tech to make more room for the function of the galley and to ensure smooth animations in the headset. As stated earlier, to make an XR world believable, the most important factors are tracking level, stereoscopy and field of view (Cummings & Bailenson, 2015). The author hence focussed more on these factors than on galley aesthetics. This could explain the high rating in this case. 6/7 participants were able to relate their virtual designs to the real world. The reason for one participant stating 'not yet' remains unclear.

Based on the responses, it seems that all participants found the XR environment beneficial in identifying practical issues that might not have been as apparent when using physical blocks. Specific benefits highlighted by respondents included the ability to perceive true scale and height. The ease of aligning or placing components in the design. The enhanced visibility of specific elements like seats and screens, as well as the relative distance between them. A better understanding of the overall space. While most of the responses were specific, two participants expressed a more general affirmation without specifying exactly what issues XR helped them foresee.

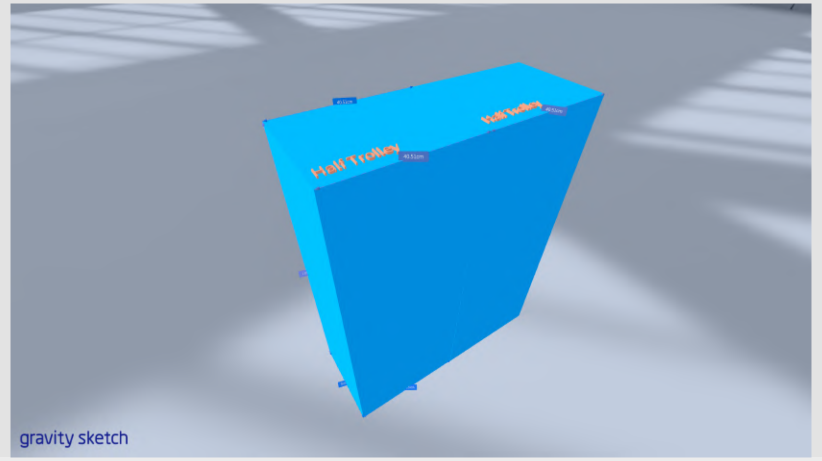


Fig. 75: A low fidelity representation of two half sized trolleys (1:1 scale) forming a full size trolley

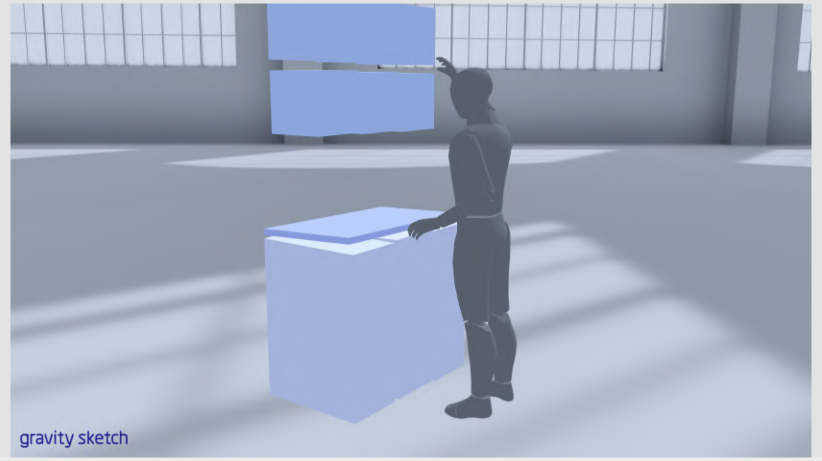


Fig. 76: Early ergonomic testing with 1:1 scale elements in XR

Transferability

The majority of participants found that shifting between mediums provided new insights, although to varying extents: Four participants noted that the shift, particularly towards XR, led to increased insights or creativity, a better understanding of measurements, or the ability to add and delete ideas:

These responses are "More insights, more creativity with XR," "It was easier to understand the measurements," "XR provides me a better insight," and "It did, and it was nice to add and delete ideas!" Another participant added the shift works very well. One participant didn't notice significant new insights from the medium shift. These responses generally suggest that shifting between physical blocks and XR facilitated additional insights and aided creativity.

Furthermore, the only challenge with the transition from physical blocks to XR was motion sickness caused in one participant who felt a bit dizzy.

6.3 Answering the Research Questions

In this section the research questions as stated in Chapter 3 will be answered:

How does the participation of different stakeholders (designers, flight attendants, engineers, etc.) influence the outcomes of the co-creative PIWs with XR and 'make tools'?

In the very first pilot workshop the designers and engineers were given a full range of 'make tools' for the co-creative session. These ranged from foam board to acoustic foam, Lego Duplo blocks, markers, stickers, Post-It's, cardboard etc. However, during the session, the preference was immediately given to the Lego blocks for quickly building and iterating the design. The designers and engineers needed little to no guidance in the design phase of the workshop. They developed innovative concepts and had a future-based outlook on the project. Their design inputs were heavily influenced by an innovative mindset, imagining the future of air travel. The outcomes of the designer/engineer session were along the lines of a futuristic vision of the future cabin, including a bar and self-service area combined with lounge and relaxation areas. These ideas were added to future PIWs to inspire the idea of a galley for flight attendants.
On the other hand, flight attendants in the first PIW needed more guidance on using the tools. After the first workshop, the toolkit was updated to contain more elements to give flight attendants more options to create.

The author hypothesised that this would make things easier for the flight attendants. It could be due to different participants or added elements in the following workshops, but little to no guidance was needed after this. In all cases, the flight attendants preferred a 3D toolkit as the preferred way of working instead of any other materials provided, demonstrating the usefulness of tangible, spatial tools.

Flight attendants brought a more hands-on experience and a deep understanding of how aircraft and passenger experience work compared to the engineers and designers. They were very service minded and attentive to the number of passengers they had to serve. Furthermore, they also were in favour of their own personal spaces where passengers could not disturb them so that they could recharge and be of better service to the passengers. In 4/5 of the cases, they came up with innovative ideas the facilitator had not expected. As these 'out of the box' ideas emerged, they had a snowball effect on all of the participants, making them come up with and use the 'make tools' to expand upon the established ideas.

In short:

- Designers and engineers: Preferred Lego blocks for quickly building and iterating designs and required minimal guidance. Their outcomes were innovative and forward-looking, envisioning futuristic cabin designs.
- Flight attendants: Initially required more guidance but adapted well to the toolkit's updates, highlighting the value of a 3D toolkit. They brought hands-on experience and a deep understanding of passenger service and experience, which led to unexpected, innovative ideas.
- Both groups benefited from the XR experience, elaborating on initial ideas and fostering creativity. This seems to be a common reaction across different stakeholders.


Fig. 77: The building ground of the pilot workshop
Fig. 77

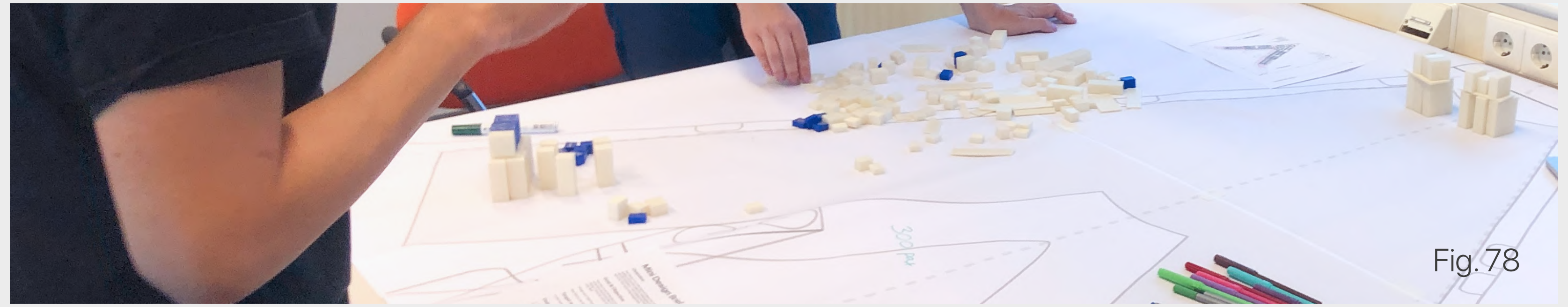


Fig. 78


Fig. 79

Fig. 78: The first PIW. Upgraded materials include custom 3D printed blocks and a floor plan on poster sized paper
Fig. 79: The pilot workshop using a wired HMD

How can the integration of physical objects and Extended Reality (XR) enhance the co-creation process in the design of the Flying-V interior?

Sanders (2006) mentions that three-dimensional toolkits can be of great benefit when designing future layouts and running through hypothetical scenarios of the future. She mentions that the more 3D or full-scale it gets, the better the results will be. During the workshops with KLM, the workshop facilitator provided both 2D and 3D 'make tools' for flight attendants to interact with. The only 2D element that, in the end, was used by the participants was the floor plan of the Flying-V. Cutable 2D seat configurations were left untouched, and although drawing on the floor plan was encouraged, this was only done minimally. The facilitator continued to exclusively provide 3D 'make tools' in the form of a 'dollhouse' kit (Sanders, 2006) in the next prototype iterations.

In all but the very first prototype iteration workshop, a design for the galley placement in the Flying-V using the 'dollhouse' kit emerged within minutes. The pieces were designed to be ambiguous enough to facilitate the emergence of new ideas whilst also being able to be used as existing equipment. In the third prototype iteration workshop, one flight attendant was working with the physical toolkit while the facilitator and another flight attendant were simultaneously working in XR on the same assignment. The physical toolkit proved to be a much faster way of working.

The flight attendant working with the physical toolkit needed to wait on the facilitator and the other flight attendant to finish their design in XR. This could have been due to the fact that there is virtually no learning curve when using a physical kit, as can be seen in the questionnaire results where participants using both XR and physical models rated the ease of use of the physical toolkit with an 8.8/10 compared to a 7.9/10 with XR. The facilitator supporting the flight attendants in their ideas did have sufficient experience to model quickly and mock-up elements in the XR world. However, they still finished later than the flight attendant using the physical kit.

As mentioned earlier, most participants found that shifting between mediums provided new insights. These included increased creativity or a better understanding of measurements and the ability to add and delete ideas. Participants furthermore self-rated the stimulation of their creative thought with an 8.9/10 when using XR.

In comparing prototype workshops 4 and 5, it became clear that using physical blocks was not only easier but also inspired as many ideas among participants as using XR exclusively on a 1:20 scale model. This suggests that starting with physical blocks and then transitioning to XR could offer additional insights. The shorter time in XR also minimises the chances of "cyber sickness", which was observed in half of the participants during the workshops. The facilitator wrongly assumed all flight attendants were less prone to motion sickness due to working on board an aircraft. Furthermore, according to Barnard (2023), people do not like to stay in XR longer than 30 minutes, especially if they are new.

While exact measures were not taken, there is still room to discover whether the transition from physical blocks to XR at the same 1:20 scale stimulates as much creativity as scaling from a 1:20 model to a 1:1 scale. Despite this, it was observed that all participants generated fresh ideas when transitioning from a physical 1:20 model to an XR 1:20 model, especially during group presentations where the models became interactive talking objects for the flight attendants to gather around. Considering feedback that suggests enhanced spatial understanding is a key factor in stimulating creativity, it appears that transitioning from a 1:20 model to a 1:1 scale could result in the most significant benefits.

Integrating physical objects and XR gives participants a comprehensive understanding of the design space in the co-creation process. The facilitator(s) observed that the immersive quality of XR and the tactile nature of the physical objects allow participants to visualise, iterate, and refine their designs effectively. The physical objects have been found to be beneficial for laying out the groundwork of the design, whilst the add-on of XR enriches the design and deepens it.

This deepening of the design leads to conversation amongst participants enhancing collaboration and creativity whilst broadening the understanding of the design context. Furthermore, introducing XR in a later phase of the co-creation session acts as a catalyst for heightened engagement and creativity. This is primarily due to the novelty and excitement associated with a fresh medium, as observed by the facilitator(s), effectively preventing potential stagnation in the creative process.

In short:

- Three-dimensional (3D) toolkits are highly beneficial for design processes, enabling better results than two-dimensional (2D) tools.
- Participants preferred interacting with 3D physical models over 2D elements in the design of the Flying-V interior.
- Working with a physical toolkit was found to be faster than working in Extended Reality (XR).
- Using physical objects is beneficial in the initial design stages, and transitioning to XR at a later stage further enriches the design.
- Switching between physical and XR mediums boosted creativity and understanding of the design context among participants.
- Using XR at a later stage of the design process enhances engagement and creativity and helps prevent creative stagnation.

Fig. 80: Different coloured blocks allowed participant to assign them different function e.g. pink was used for trash

Fig. 81: Participants all being immersed in XR and viewing the Flying-V on a 1:20 scale

What benefits and limitations are associated with using physical objects and XR in a co-creative design process?

Physical objects or 'Make tools' have been proven to work in various contexts (Sanders, 2006) (Sanders & Stappers, 2012) for enhancing creativity and building future layouts and scenario's in co-creative workshops. In the PIWs facilitated by the author, these benefits became apparent by the quick and playful nature these tools inspire in the participants.

Participants in all of the workshops could use the 'dollhouse' toolkit with a small instruction on how to view the pieces provided. The quick and playful nature of the toolkit became apparent and was adapted quickly. Layouts and galley ideas were drafted, and pieces were used to the preference and imagination of the participants. For instance, using bricks that could represent coffee machines as coffee machines, but also using the same bricks to build scaffolds for a worktop of a bar. In the fourth PIW, participants got creative not only with the intended materials but also used other materials, such as Post-It's, to build their physical mock-ups.

Because there is virtually no learning curve involved in using this method, it makes it suitable for a wide range of people that may be part of a co-creation workshop. They can stimulate and facilitate the creation of their own innovative ideas in a low-resolution adaptable way. Because of the hands-on nature of the toolkit, participants are not afraid to build on each other's ideas and to use and share blocks from their fellow participants, in turn inviting conversation and discussion between the participants. Participants rated the confidence of their spatial designs using physical objects an average 7.7/10. The ability to reason about space in XR was higher, with a 9.1/10.

As stated by Sanders (2006), "the more full scale it gets, the better". The 'make tools' could provide an overview of the galleys in the Flying-V up till a certain point. However, they could by design not provide a full-scale experience.

In creating a new operating theatre by Roubos & Beekman (Sleeswijk Visser, 2013), physical objects were used to mock up the layout of a new operating theatre. This was done with doctors, nurses and other hospital staff. After the layout was complete, old hospital equipment was used to do a full-scale (scale 1:1) mockup. At this point in the Flying-V workshops, the facilitator introduced XR into the process. The benefit of using XR in this stage was to be found in the immersive and spatial aspects of the technology. But also in the logistics of only carrying multiple HMDs instead of full-size mock-ups and equipment.

As stated earlier, a significant benefit of introducing XR in this workshop stage was the technology's ability to stimulate the participants to develop more ideas. XR facilitated the expansion of the initial ideas made by the flight attendants with the physical 'make tools', building and expanding upon first ideas, making them richer, more in-depth and closer to real-world scenarios.

However, the virtual and physical tools do not have a direct live connection. Everything made in the physical world must be modelled and placed in the virtual world by either the facilitator or an assistant. 'Make tools' furthermore have a finite set of items in the toolkit, which could limit the number of designs participants can make. XR, on the other hand, has a virtually unlimited set of items to bring into the virtual world.

In this sense, the two techniques complement each other and fill in the missing pieces for each other. In the best case, physical and virtual elements would have a direct live connection making moving in the real physical world synonymous with moving in the virtual world and feeding this directly into XR. A 1:20 scale physical model could be experimented with, and a live 1:1 scale XR model could verify whether these changes are justified. This would, however, contradict the finite and infinite possibilities between the physical and virtual worlds. Also, in the context of the timeframe of this thesis, this would not have been a realistic goal to develop.

One participant mentioned it was hard with 'make tools' to show how objects would be placed 'in the air' and that with XR, this is easier. One untested solution for this could be to make transparent objects that represent empty space to place other parts on.

Benefits of Physical 'Make Tools':

- They enhance creativity and enable quick layout drafting.
- They require minimal instruction, leading to easy adoption.
- Their hands-on nature encourages participants to build on each other's ideas.
- They invite conversation and discussion between participants.
- All participants rated their confidence in their spatial designs using physical objects at an average of 7.7/10.

Limitations of Physical 'Make Tools':

- They do not provide a full-scale experience.
- They consist of a finite set of items, limiting the variety of designs that can be made.
- There is no direct live connection with the virtual world; physical creations must be manually modelled in the virtual world.

Benefits of XR:

- It offers immersive and spatial aspects, enhancing the understanding of the space.
- It facilitates the expansion of initial ideas, making them richer and more in-depth.
- It provides a virtually unlimited set of items for design.
- The ability to reason about space in XR was rated higher than with traditional 'make tools': a score of 9.1/10.

Limitations of XR:

- XR requires additional effort and resources to model and place physical designs into the virtual environment.
- Ideally, XR would have a live connection with physical elements, which currently isn't the case.
- While XR has virtually unlimited possibilities, there is a limitation to what can be expressed in the physical world.
- Motion sickness or cybersickness can easily be induced if hardware and software do not cooperate right.
- It needs a facilitator, or someone experienced in XR design to guide participants and for proper equipment handling.


Fig. 82


Fig. 83

Fig. 82-83: scenes from the PIWs

How does using XR and 'make tools' in co-creative design affect the final design outcomes?

Using physical 'make tools' and XR in a co-creative design process influences final design outcomes in the following ways: 'make tools' facilitate rapid, collaborative idea development, serving as a foundation for creativity. XR complements this by adding a generative design layer, stimulating participants' spatial understanding and imagination, thereby allowing a more in-depth exploration of initial creative ideas than using physical 'make tools' alone.

Moreover, XR offers the ability to create quick mockups with variations in colour and material of designed objects, providing immediate ergonomic feedback. This leads to a more refined initial design and reduces ambiguity in later design stages, potentially streamlining the overall design process and enhancing final results.

Despite the low graphical fidelity of the XR environment utilised in the PIWs, participants rated its realism highly, with an 8.4/10 score. This indicates a high level of participant satisfaction and the capacity of XR to represent a real-world galley, convincingly bridging the gap to a final design for a galley. Additionally, 6 out of 7 participants confirmed their ability to relate their virtual designs to real-world scenarios.

Furthermore, XR provided a platform for identifying practical issues that might not have surfaced with the sole use of physical blocks, showcasing its added value in foreseeing and addressing design problems.

In short:

- Physical 'make tools' quickly generate collaborative ideas.
- XR enhances these ideas by stimulating spatial understanding and allowing for varied mock-ups.
- Despite its low graphical fidelity, XR is rated as highly realistic by users.
- XR can reveal practical design issues, adding value to the design process.

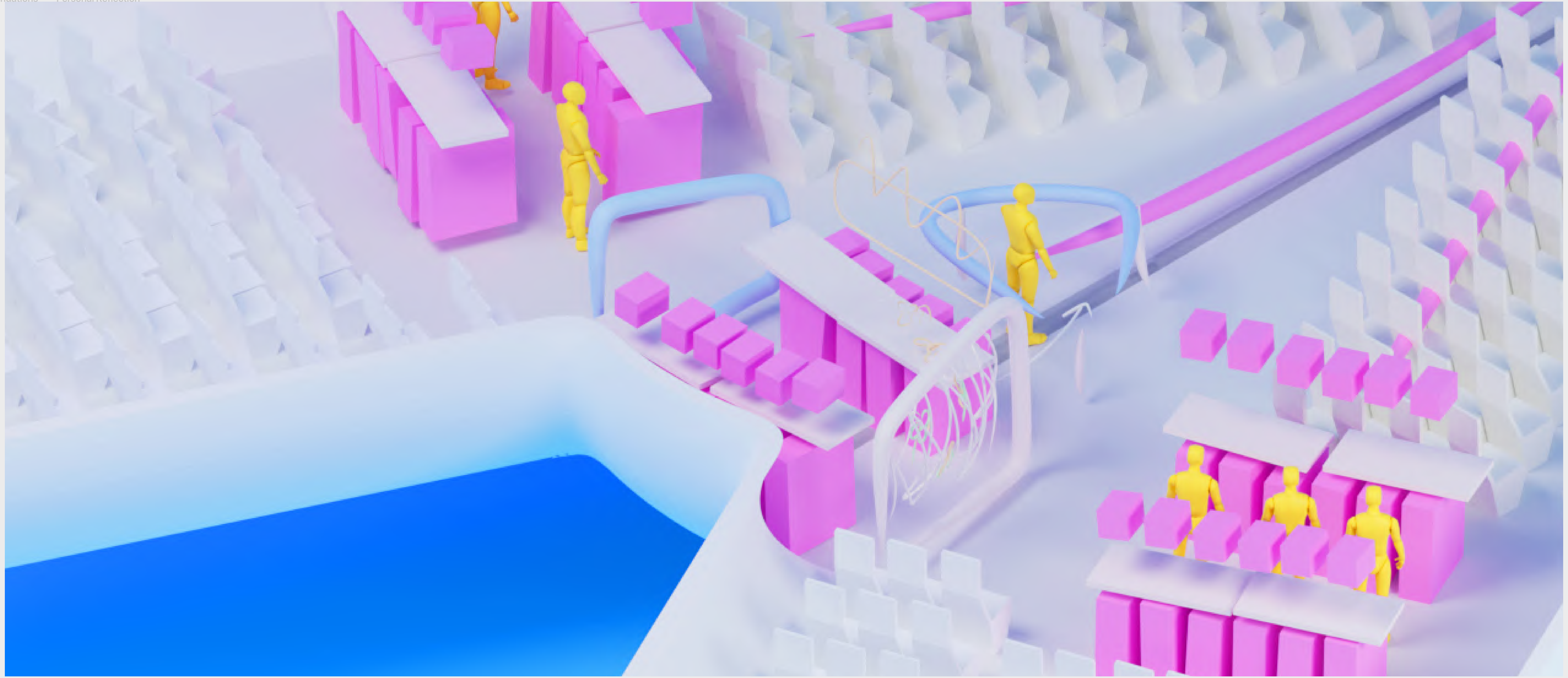


Fig. 84: A rendering from the galley layouts designed in PIW 4

6.4 Galley Positions

From the PIWs, several galley designs and positions emerged. These will be listed on this page individually, with a short description of each.

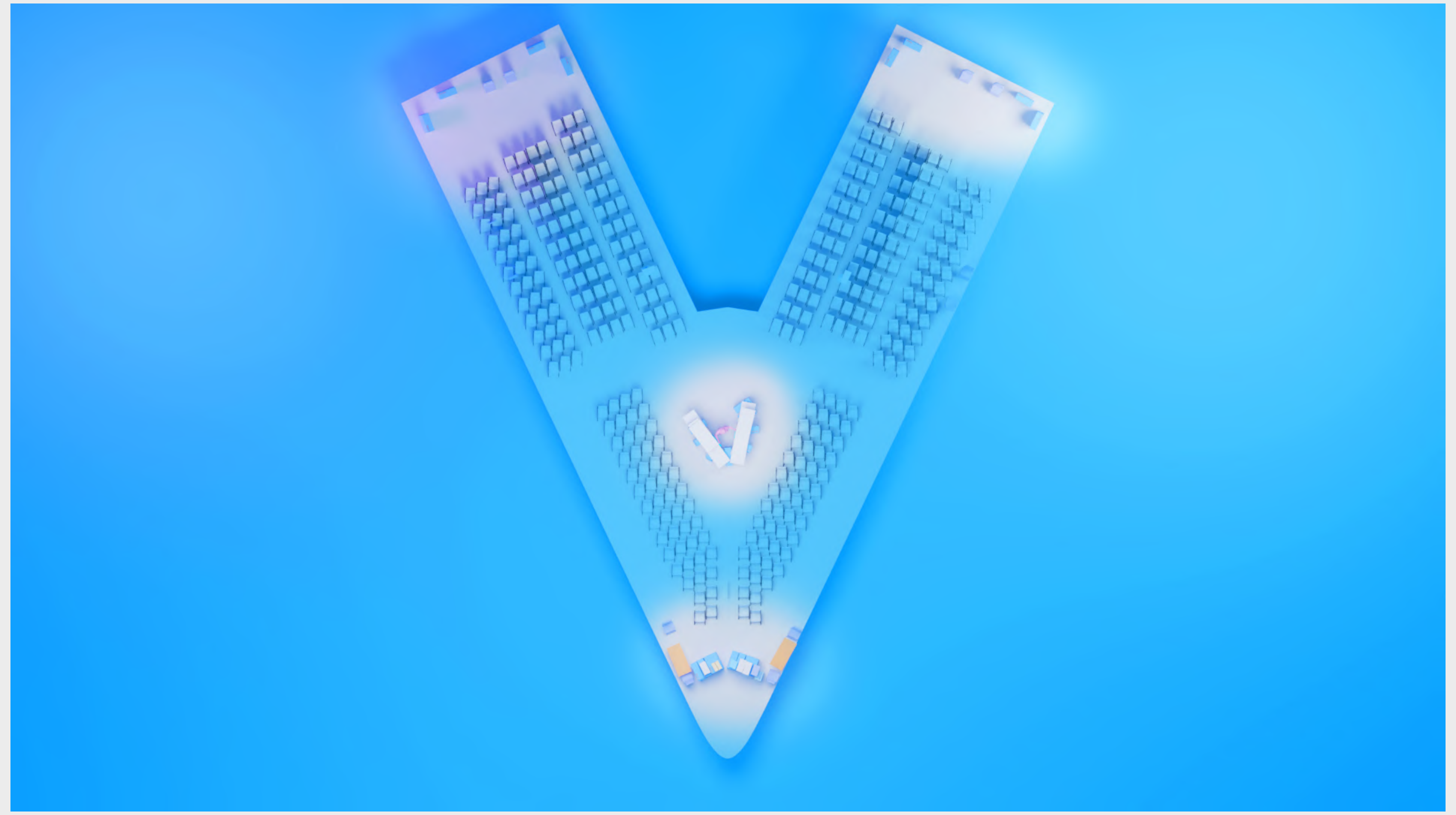


Fig. 85: Flight attendants from workshop 2 would like to see a V-shaped bar in the middle of the aircraft with supporting galleys in the front and in the rear. Chairs are removed in the rear since a galley next to passengers was not desirable

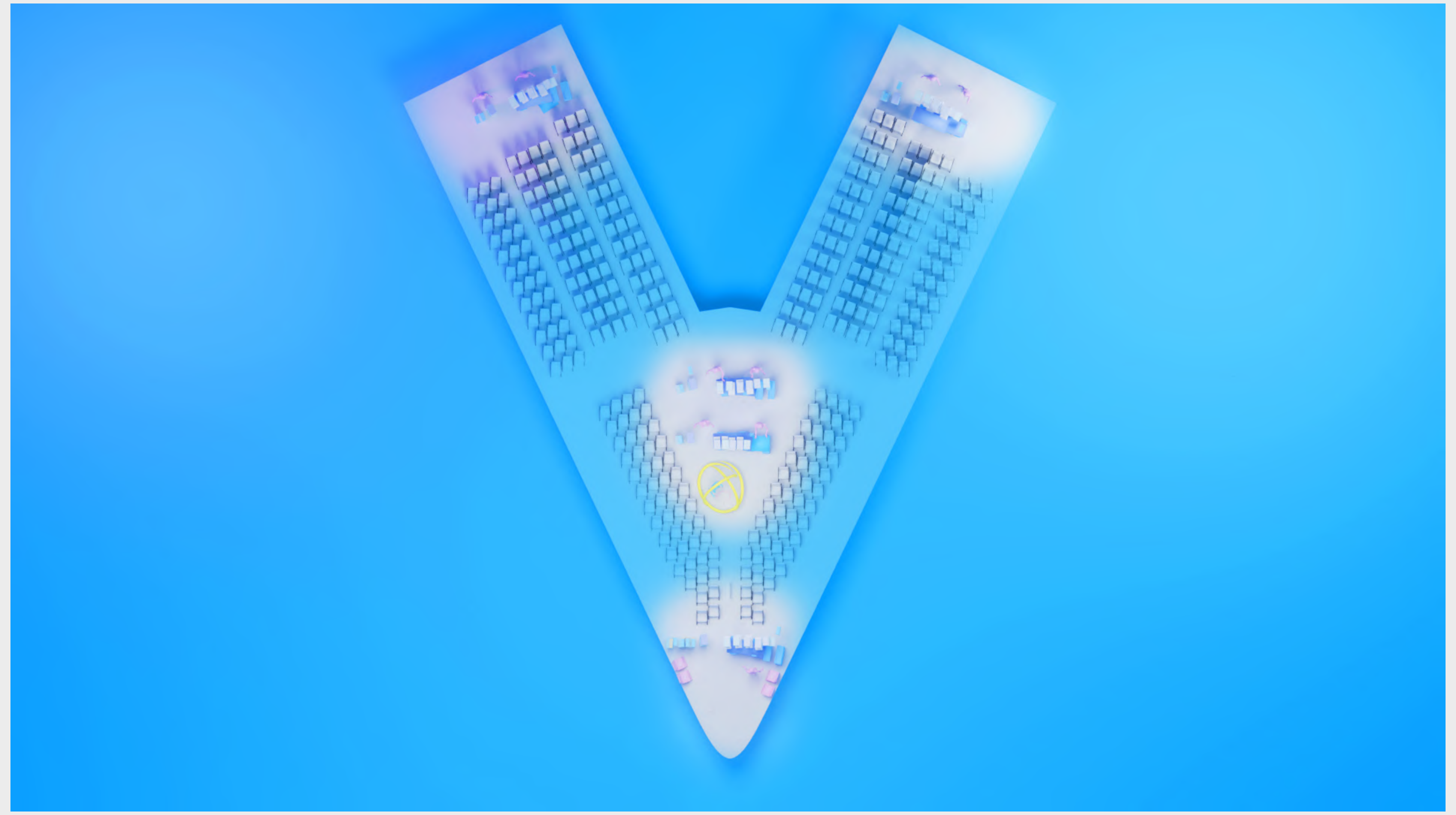


Fig. 86: Flight attendants from workshop 3 suggested a bigger galley in the middle of the aircraft with a prayer or yoga area in front. Additional galleys are place in the front and in the rear.

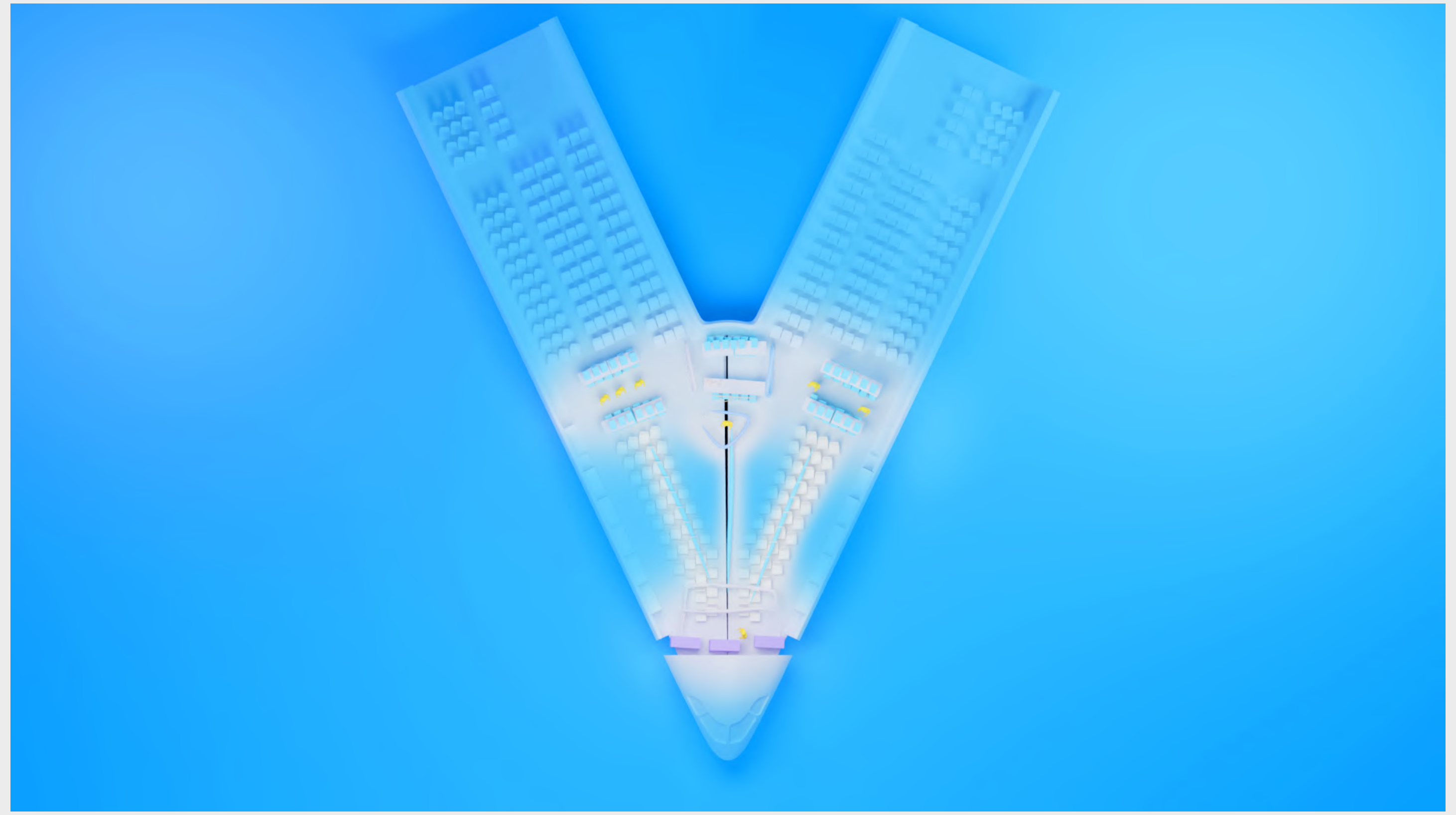


Fig. 87: Flight attendants from workshop 4 suggest one large galley in the centre of the aircraft with a crew chill or resting are potentially in the front. They liked the fact that you could walk through the galley from door to door.

XR+

7

7.1 Introduction

In the ever-evolving landscape of design, integrating emerging technologies such as XR with traditional design methods offers exciting new avenues for exploration, as demonstrated in the PIWs. This chapter will present a novel design methodology in co-creation that combines the tangible interaction of physical objects with the immersive potential of Extended Reality (XR). Leveraging the unique strengths of both mediums, this method seeks to enhance the design process and the co-creative design process by providing a dynamic, iterative, and multi-sensory design experience.

Grounded in insights derived from a series of PIWs focused on the design of the galley of the Flying-V, this method aims to enhance creativity, improve spatial reasoning, and facilitate a deeper understanding of design contexts among participants. It explores a transition from the physical to the virtual, from initial design ideation using 'make tools' to elaborative design in XR.

This approach allows participants and designers to draft layouts quickly, play with ideas, and build upon each other's concepts using physical objects, thereby enhancing creativity and promoting discussion. Simultaneously, XR is a powerful tool for expanding on these initial ideas, providing an immersive experience that gives participants a sense of scale and spatial orientation that is hard to achieve without investing significantly in resources.

This chapter presents a design methodology specifically tailored for the German Aerospace Center (DLR), based on the learnings from the prototype iteration workshops: XR+

XR+ is a method that has been crafted to be implementable with DLR's current resources or those that could be realistically acquired. The method is expected to be used by designers since they have the know-how and skills for using XR and crafting physical mock-ups. Hence this description will only go to a certain level of detail.

This chapter will provide a step-by-step guide to implementing this method, from setup and ideation using physical 'make tools' to transitioning into XR. The method aims to establish a new design methodology that maximises the benefits of both physical and virtual design tools, ultimately leading to richer, more innovative, and practical design outcomes.

7.2 Application

It is worth noting this method is part of the bigger design process and functions as a tool to add to the existing design process. It finds itself in the fuzzy front end of design, where room for experimentation and ideas exist. Hence, this method should be considered part of early co-creation during the design phase.

As mentioned in the introduction of this thesis, the cabin design process is a lengthy and costly matter. It is initiated based on identified wants and needs through customer surveys and questionnaires. This method aims to alleviate some of the bottlenecks in the traditional cabin design process for DLR. It is focused on, but not limited to, the initial concept and design space of the cabin design process for (in this thesis) the Flying-V. This means that not just cabin interiors could be designed by this process, but that it is also applicable in other scenarios and suitable to use multiple times and/or in later stages of the design process.

The method was developed to streamline stakeholders', and user needs early on in the design process in order to create a greater chance of an efficient and successful continuation of the design process.
Inspired by the 'make tools' of Sanders & Stappers (2012), this method aims to elevate the physical three-dimensional tools that work in other (interior) co-creation sessions and expand their capabilities to bring ideas closer to the final design deliverable.

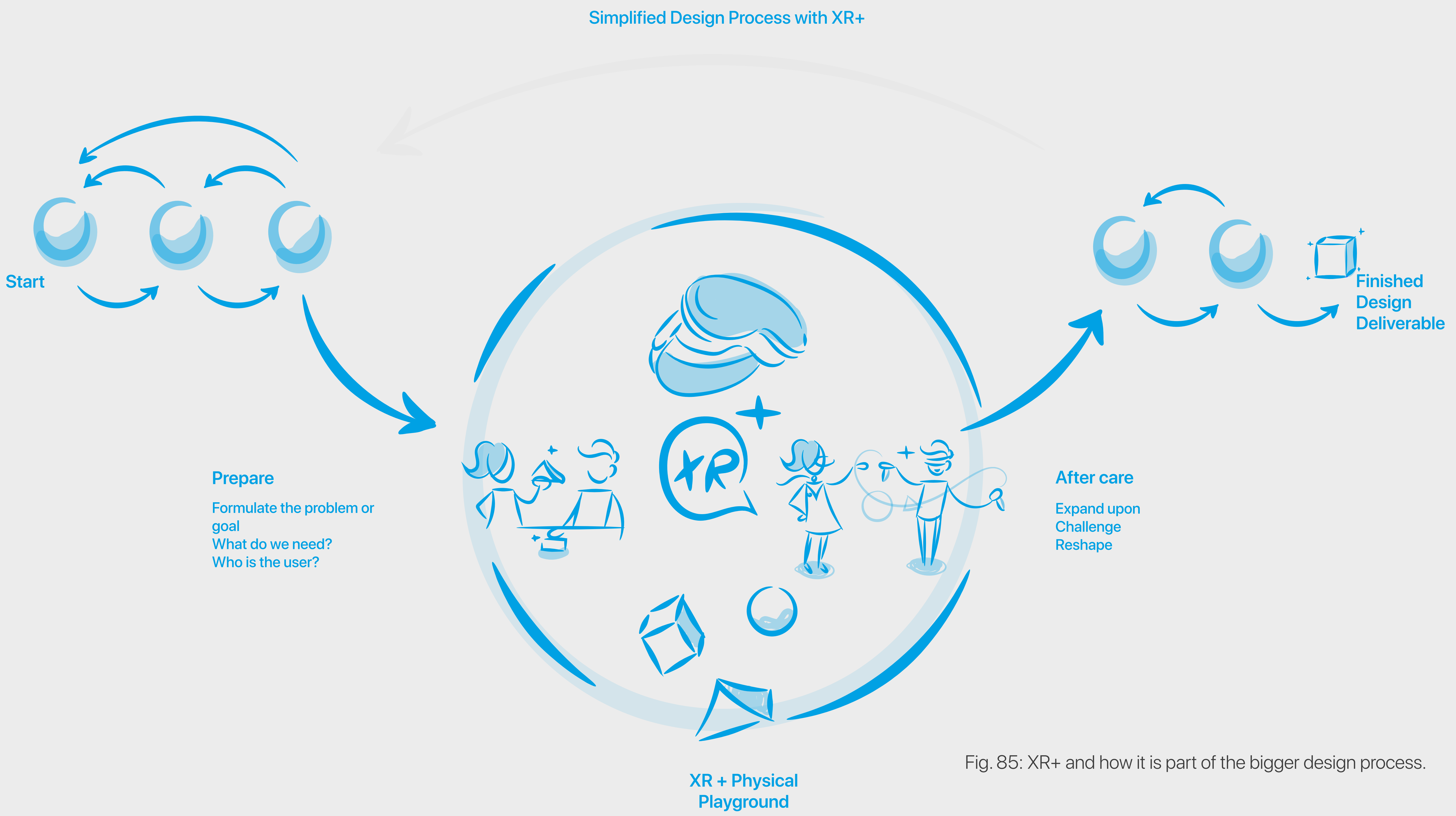


Fig. 85: XR+ and how it is part of the bigger design process.

Fig. 86: The setup for the second phase of PIW 4

7.2 Application

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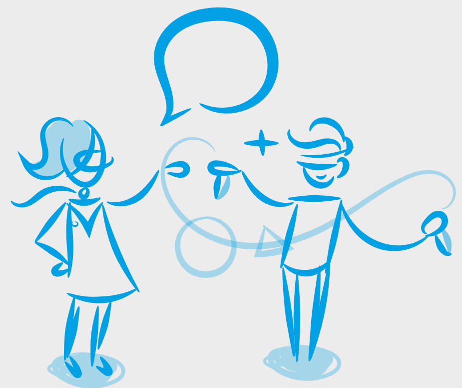
Goal:
To encourage DLR to collaboratively design with end users by facilitating a co-creative process that combines the physical world and the XR world to spark innovative new concepts.

Roles and responsibilities:
Before a co-creation session can begin it is beneficial to know that there are several key roles that people can take on during a session. Each of these roles plays a part in the success of the session. This method is written with the facilitator in mind. However, there are multiple roles involved in this workshop. They will be explained separately bearing in mind that one person can take on multiple roles and will usually be required to do so.



Facilitator:
This person is in charge of directing the flow of the co-creation session. They guide the conversation, encourage participation, manage the use of tools, and ensure that the objectives of the session are met. The facilitator also helps set the tone of the session, making sure it's both productive and enjoyable. Their role includes introducing the workshop's goal, the tools that will be used, and the process that will be followed. Ideally the term can be described as 'design facilitator'.

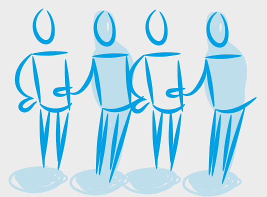
Participants:
The participant is arguably the most critical person in the session. The participant represents and is the end-user for whom the design deliverable is being designed. In the most desirable case these end-users are part of the co-creation session, contributing their insights, needs, and wants directly to the design process. When end-user participants are not directly available a session can be hosted with participants playing the role of these end-users. However, more work for setting up such a session is necessary, such as sensitising, and results may differ from actual end-users. For a pilot workshop this is recommended, however, from the PIWs it was found it is always best to use actual end-users.

Designer:
Ideally the facilitator of the session is a designer who can effectively support participants in their role of 'co-designer'. In a co-creation context, participants become 'co-designers' and assume the role of designer to a certain extent. The goal of co-creation is to get diverse perspectives and ideas, so everyone's contribution as a 'co-designer' is valuable.

3D Modeller:
This role is crucial for creating both the physical and virtual objects used in the workshop. Utilising Blender, Rhino, Gravity Sketch or any other 3D (CAD) software to create 3D models. These can then be printed using a 3D printer for the physical part of the co-creation session. They would also be responsible for preparing virtual objects in 3D software such as the former mentioned programs for display in XR. However, it is expected that the designer is proficient in technologies, hence the role can be seen as one being adapted by the designer.

Technical Support:
An optional role could be that of technical support. This person ensures that the technological aspects of the session like the XR equipment works smoothly. They might help troubleshoot technical issues, assist participants in using the technology, and manage any digital assets. This could lift the burden of the design facilitator(s) making them only concerned with facilitating the session and not focussing on the technical problem-solving.

Observer:
Another optional role could be that of the observer. It became clear in the PIWs that having a second facilitator act also as an observer improved the efficiency and overall flow of the session. By providing feedback to the main facilitator during the breaks the session could be improved and tweaked on the go accordingly.



Many roles can overlap and might be taken up by the same person. For instance, in the PIWs the main facilitator was, except for the role of participant, all of the above roles in one person. The second facilitator acted as facilitator, designer & observer.

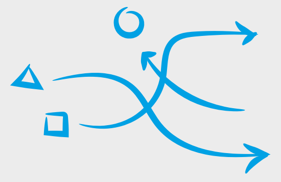
The following lists additional facilitator guidelines as discovered in the PIWs. These factors emerged during the PIWs and were found to be important to the author for designing the next PIWs. These can serve as a reminder or checklist. Some might seems obvious but can be easily overlooked

Practical

Engage in Early Planning:
The facilitator should familiarise themselves with the goal of the workshop and the expected deliverables. They should keep the end-user of the design deliverable in mind and consider the type of participants that will be needed. Furthermore, it is also good to think about what materials will be required and what the activities leading up to the session should be.

Select Your Users/Participants:
The facilitator should identify and select the right participants for the workshop. Questions about who will be involved with the end-design deliverable should be considered.

Plan Logistics and Location:
Consider the physical and virtual requirements of the workshop. Ensure that the location and technology support the session's activities and that all materials and resources are prepared in advance. Ideally set up the room the night before the workshop so everything is ready to go the next morning.



Design Workshop Materials:
Create and organise all the materials needed for the workshop. This could include designing physical and virtual objects, preparing the necessary software, making sure there is enough stationary supply etc.

Explaining the Exercises:
Clearly articulate the steps of each exercise, making sure all participants understand what is expected of them.

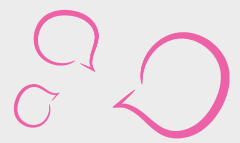
Wrap-Up:
At the end of the session, summarise the outcomes. This can serve as a reflection point that allows participants an opportunity for final input or adjustments if required. Thank the participants for their time and contributions. Optionally a small gift is always greatly appreciated by the participants. This does not need to be complicated or expensive. A bar of chocolate goes a long way.

Social

Welcome and Intro:
Make participants feel comfortable and explain the goal of the workshop.

Have an open, approachable attitude:
Maintain a friendly and welcoming demeanour throughout the session. Encourage participation, be open to questions, and create an environment where everyone feels comfortable contributing.

Reserve Judgement:
As a facilitator, it's important to remain neutral and avoid passing judgment on participants' ideas. Encourage free thinking an appreciate all input.



The facilitator's role is crucial in the co-creation process, guiding participants through the steps and ensuring a productive and enjoyable experience for all.

STEP 1: Pre Workshop

For a successful and streamlined co-creative session, the method is broken down into stages. Examples of the Flying-V will run throughout the stages to provide guidance and practical examples.

Preparing the collaborative session:
This stage takes place before the actual workshop. It is essential to know what will be designed and for what context. In other words: determine what must be designed and for whom. Reach out to the end users of the design deliverable. In the case of this thesis, the KLM cabin crew are the end users of the to-be-designed galley (or something fulfilling a similar function) of the Flying-V

To ensure a successful and efficient co-creative session, the process is divided into different stages, each contributing to the overall design process. The Flying-V project will be used as an ongoing example throughout these stages, offering both guidance and tangible insights.

Through the Prototype Iteration Workshops (PIWs), it was found that a structured process beginning with immersion in the current or existing context, followed by designing the new context and concluding with immersion in the new context, proved to be most effective. This approach is loosely based on the "Path of Expression", as can be seen in figure 86 and as proposed by Sanders & Stappers (2012). Here the present is observed first, then past experiences are recalled. A reflection is made on the past and from here possible futures are imagined.

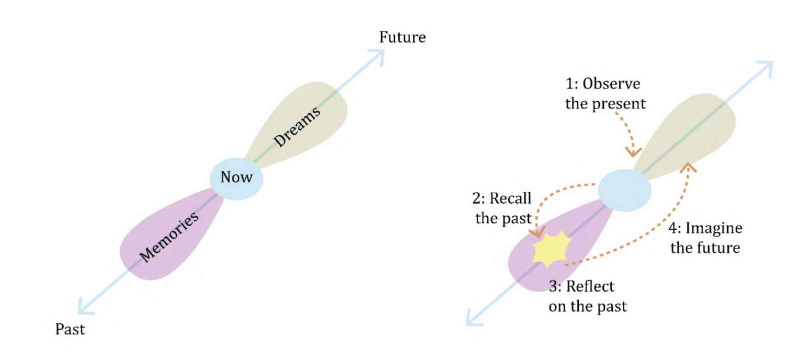


Fig. 87: The path of expression. Sanders & Stappers (2012)

Materials Needed:

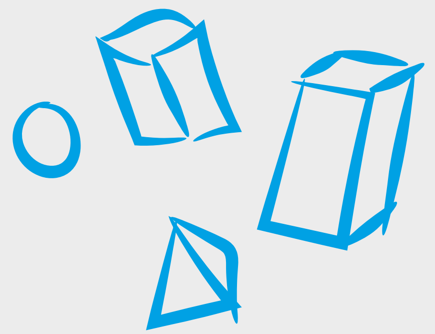
Arts and crafts materials, foam board, foam, cardboard, Lego, markers, paper, glue, tape, etc!

Software:
3D software capable of creating models for 3D printing, such as Blender or Rhino.
Slicer software such as Prusa or Cura.
Gravity Sketch

Hardware:
An HMD capable of running Gravity Sketch. It is urgently recommended the HMD works wirelessly and standalone such as a Meta Quest 2 or Pro.
A 3D printer such as an Ultimaker S3/S5 or Prusa.
A notebook computer able to display keynote presentations

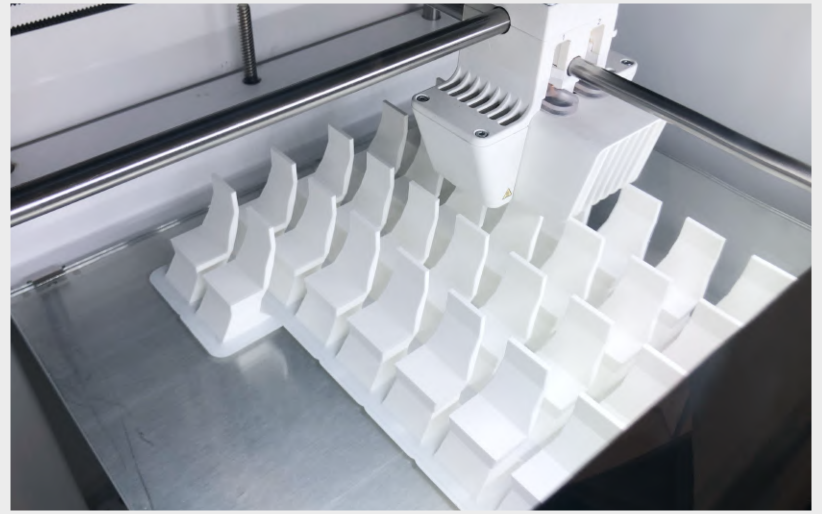
● In current DLR inventory

Preparing your objects
The co-creation workshop will involve participants making and creating things. According to Sanders & Stappers (2012), it is important to provide scaffolds for people at the making level and to offer a clean slate to people at the creation level. In a practical sense, this means making tools that are ambiguous enough to be used to create new ideas whilst also providing objects that serve people's needs at the making level. During the workshops hosted by the author, it was found to be beneficial to use both concrete and ambiguous objects and to use these to complement each other in case participants become muddled or too fixated on their ideas.



Case example:
In the case of the galley of the Flying-V, ambiguous white blocks were used to build and create freely. Labelled blocks with names such as 'trolley' or 'container', miniature chairs and mannequins provided more scaffolding on the making level. In unison, they provided a balanced amount of vagueness to create freely and concreteness, not to get too muddled.

Preparing your physical objects
There are many ways in which you can prepare physical objects or your 'make tools'. Firstly prepare your 2D assets. After this, you can fill in the gaps with 3D assets. It is recommended when designing an interior first to print the floor plan or top view to get a sense of scale and overview of the space you are working in. After this, materials such as foam, foam board, Plexiglas, and dollhouse objects can serve as physical objects in your co-creation process. Rapid prototyping techniques like laser cutting and 3D printing give you the advantage of fully controlling your preferred items to use for your toolkit and to which scale. However, these can be time-consuming to make. Once all your physical objects are 'co-creation session ready', you can begin crafting your virtual objects.



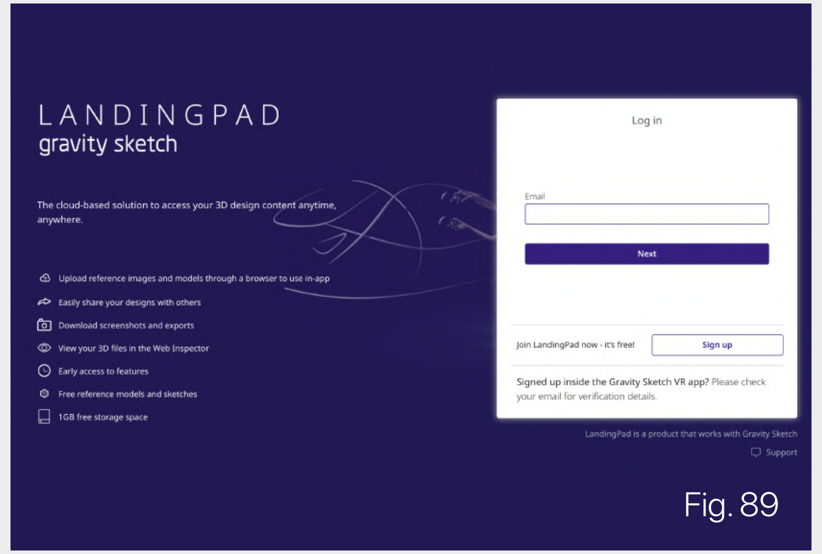
Case example:
Given the need for designing to scale, it was necessary to create a floor plan for the Flying-V. This was done in Adobe Illustrator on a 1:20 scale, aligning with the final thesis design of the Flying-V floor plan by Wamelink (2021) and initial floor plans of the Flying-V provided by the Aerospace Engineering Faculty in Delft.

In the workshops, a choice was made to utilise 3D objects or a 'dollhouse' kit. These various items were based on regular equipment found in a typical galley, including 1:20 scale trolleys, half-sized trolleys, containers, larger containers, water and coffeemakers, work surfaces, chairs and so on. These objects were all made using a 3D printer. Each item was initially modelled in Blender 3D Software before the files were converted into.STL format, making them ready to be printed. The slicing software utilised for this process included Ultimaker Cura and Prusa software. The choice of Blender and Cura was primarily based on their availability at DLR, which also has an Ultimaker S5 3D printer on-site.

Fig. 88: The first 3D printed chairs added to the tools

Preparing your virtual objects
Before preparing your virtual objects, ensure that all necessary software is downloaded and installed on the appropriate devices. This includes a 3D software program like Blender or Rhino on a computer and an application capable of displaying virtual objects in XR, such as Gravity Sketch, installed on multiple HMDs. The number of HMDs should correspond to the number of participants in the co-creation workshop. It's worth noting that, at the time of writing, Gravity Sketch can host multiple users in a collaborative XR session and works seamlessly with a web platform called LandingPad. LandingPad serves as a platform where 3D models can be uploaded and then viewed on an HMD within Gravity Sketch.

The preparation of virtual objects primarily involves the creation of 3D assets for the XR environment. This requires you to know which elements will be used in the physical part of the workshop. Once you have a clear view of all the physical objects used in your workshop, you can begin modelling your virtual items. A benefit of using 3D-modeled objects is that they can be imported to the XR platform with a few steps. If modelled in Blender, files need to be converted to either an .OBJ or .FBX file to work.



Because DLR has access and licences to Gravity Sketch, an XR program able to run on various HMDs, the files must be prepared to work with Gravity Sketch. To prepare the files, export them to.FBX or .OBJ and upload them to landingpad.me by logging in with your Gravity Sketch credentials.

Open Gravity Sketch on your HMD and log in with your credentials. Open a new collaboration session. A virtual world will emerge, and your models are now ready to be imported into the collaboration session. It is best to do this before starting your co-creation workshop.

Case example:
The model of the Flying-V used for testing was either an existing model modified by the author to suit the workshop's requirements or a model made by the author by combining new and existing parts. Modifications were done in Blender, and the model was exported to Landingpad and Gravity Sketch. From here, whilst wearing an HMD with Gravity Sketch running, the Flying-V model could be imported together with the other modelled items. A virtual stash of objects used in the virtual part of the workshop was used as virtual building blocks to build and iterate quickly during the workshop.

Fig. 89: The landing page of Landingpad

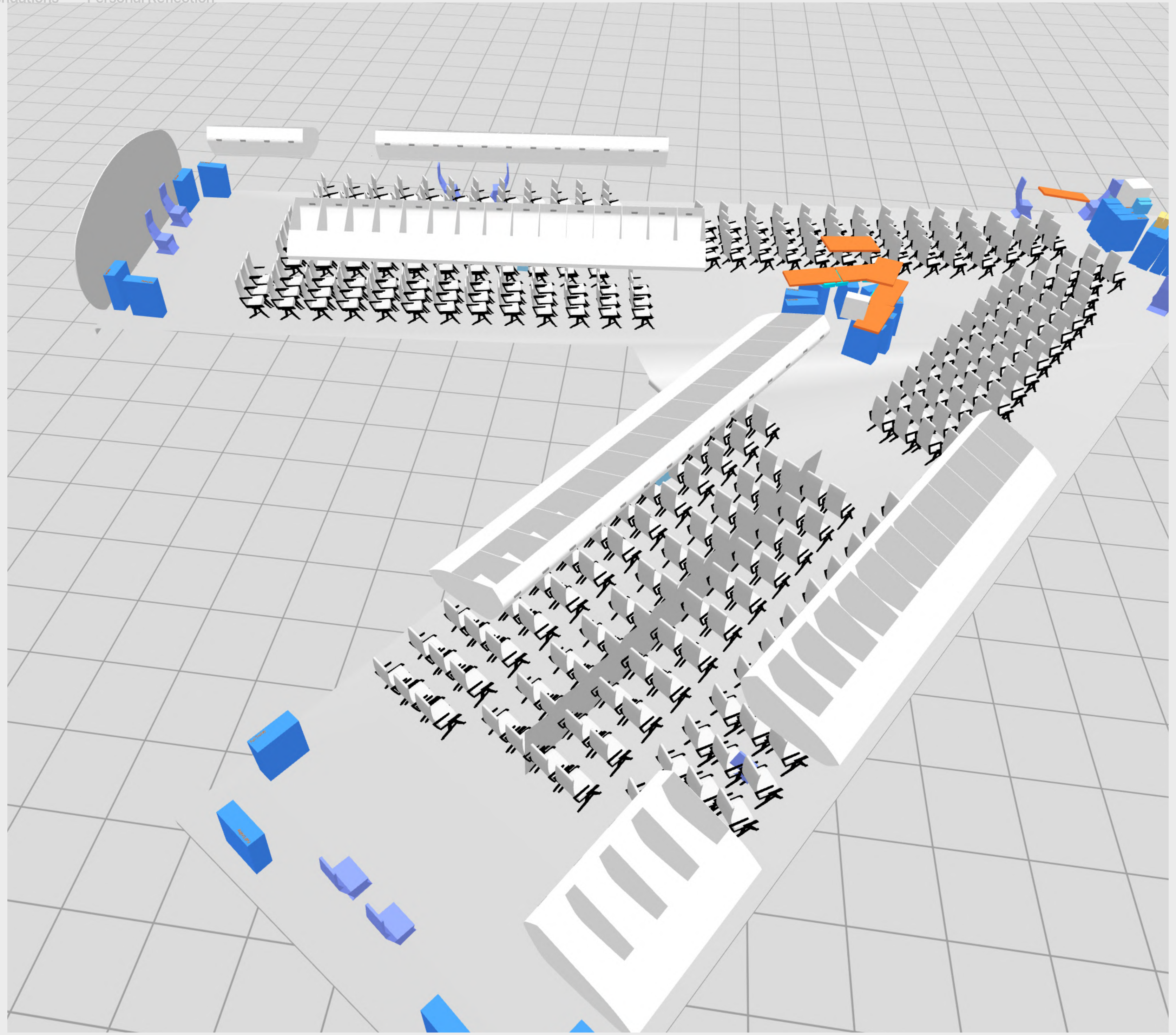


Fig. 90: The Flying-V as seen from the back with the results of PIW 2

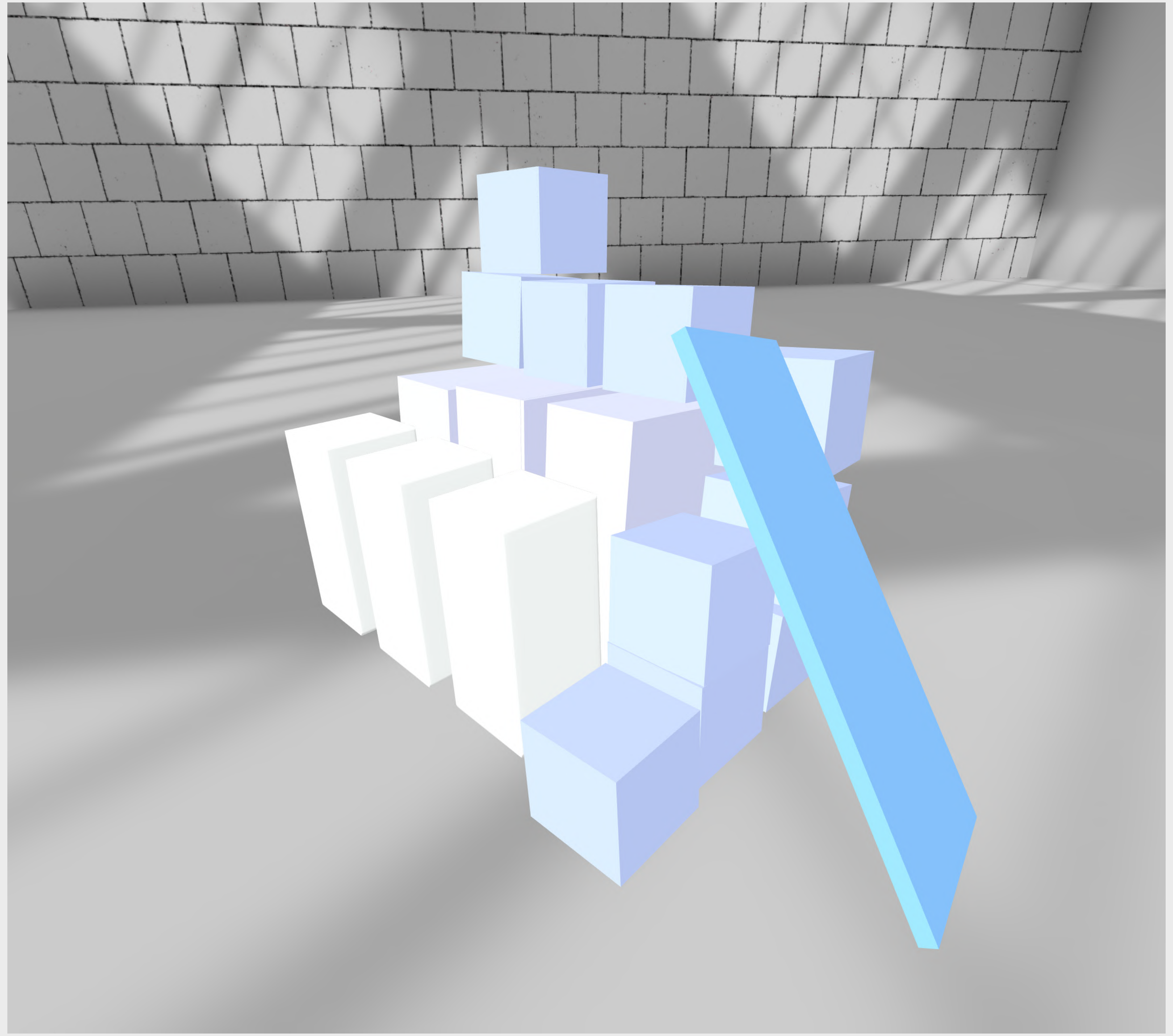


Fig. 91: The initial 'stash' of galley elements later used in the PIWs

STEP 2: Workshop Introduction

The workshop can start! In this stage, participants are introduced to the co-creation workshop. Here you, as the facilitator, briefly explain the workshop's goal, the tools that will be used and the process that will be followed. An agenda on the wall or whiteboard can help with showing the process.

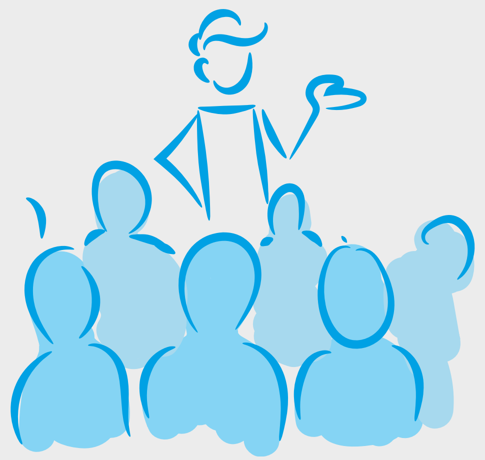
Materials Needed:
- Laptop
- Whiteboard or paper sheet on the wall
- Something to throw like a small ball

State that the reason the participants are here is that they are experts in their own experiences. These experiences are valuable for what your participants will be creating in the workshop and that you will be creating something together today. Hence the name co-creation workshop. All input is appreciated. State that they are the co-designer and the user of the specific product today. Explain they are welcome to share any experiences that come to mind and that they should not hesitate to ask, shout or share things they want to at any time in the session. Depending on the project, the immersion in the context phase can now start after an energiser.

This stage is all about breaking the ice and getting everyone on the same page. As the facilitator, it is your responsibility to clarify the workshop's objectives, introduce the tools to be used, and outline the process to be followed. To provide a clear road map of the proceedings, consider sketching an agenda on a wall or whiteboard.

The participants should understand that they are the experts of their own experiences. Emphasise the collaborative nature of the session—this is a co-creation workshop designed to harness the collective knowledge of everyone. Reinforce that their input is not only welcome but also crucial for the workshop's success.

Today, they don't just represent end users of the product. They also play the role of co-designers. Encourage them to freely share experiences or thoughts, and assure them that there are no right or wrong answers. Depending on the project's specifics, the immersion in the context phase can now start after an ice breaker or energiser as they were beneficial for group dynamics in the PIWs.



Case example:
In the Prototype Iteration Workshops (PIWs), the facilitator first introduced himself and provided an overview of the project mentioning the galley design for the Flying-V He also mentioned the above factors of introducing the co-creation and participants being experts of their own experiences. After the introduction, an energiser activity was implemented to set the stage for the co-creative process. All participants were asked to stand and participate in a balloon-throwing game. In turns, each participant tossed a small water-filled balloon across the room, shouting a random word as they did so. The subsequent participant had to catch the balloon and then throw it to the next person, shouting a word associated with the previous one. For instance: sky, blue, water, thirsty, beer...etc. This game, designed to stimulate quick, associative thinking, successfully injected energy and engagement into the room. For the final PIWs in the Flying-V galley project, an agenda was drawn out on a whiteboard with time slots for each planned activity. This ensured a more effective introduction and provided a reference for the facilitators and participants to fall back on in case the track of time was lost.

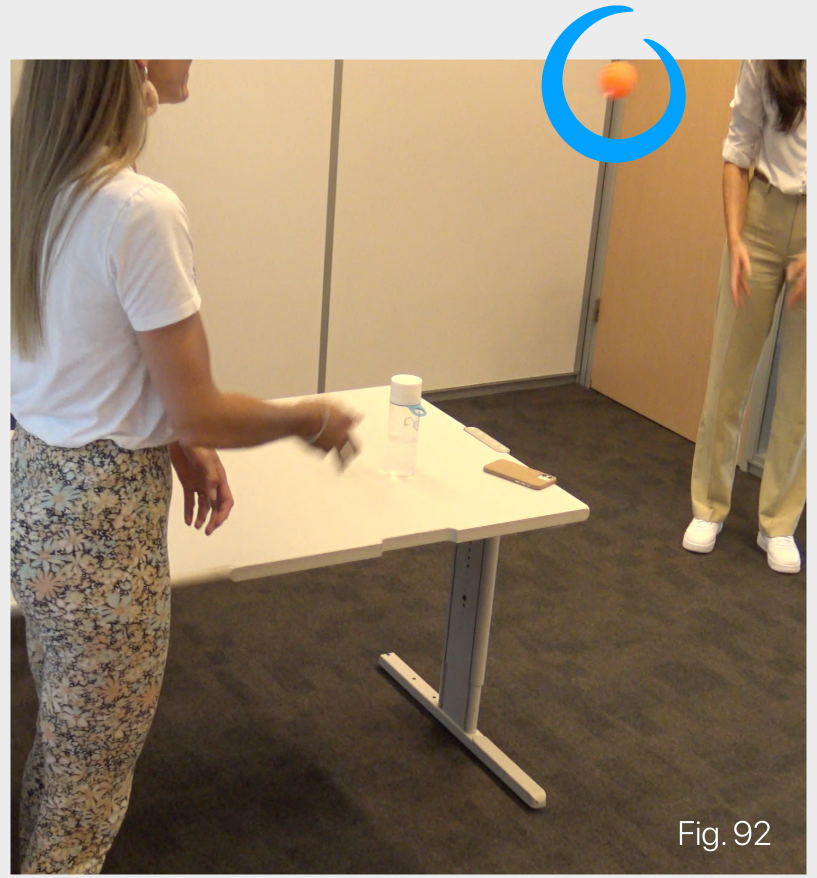


Fig. 92: The tiny balloon used as energiser

STEP 3: Workshop Context Immersion

Materials Needed:

- Post-It's
- Markers
- Big sheets of A0 Paper
- Timer
- Stickers

In this stage, it is crucial to have your participants in the same state of mind and thinking about the topic at hand. This already begins with participant selection before the workshop starts but can be further enhanced by giving them an assignment. Introduce the topic you will be designing for. This can be done by asking participants questions about the topic and letting them air their opinions.

Another possibility which was deployed in the PIWs is a so-called brain dump by letting participants fill out Post-Its with all their thoughts. Participants are encouraged to go for quantity over quality. Quantity breeds quality (Heijne, 2019). These Post-Its can then be laid out on a surface for all the participants to see each other's ideas. In this diverging stage, a lot of concepts and ideas will emerge. Parnes (1961) describes this as a three-wave process. Firstly there are the obvious, expected standard options. The first wave is also known as the 'purge'. The second wave breeds silly or unusual ideas, and the last wave is that of novel and challenging options.

For the final PIWs, participants were instructed to diverge, writing down anything that came up in them. After seeing what fellow participants had produced, the reverging stage could be initiated. The most frequent technique is spontaneous clustering (Tassoul & Buijs, 2007). There will naturally be some overlap, and similar items can be clustered. Generally, around 5-7 clusters emerge (Heijne, 2019). There might be some items that do not fit any of the clusters. These can be put into a 'rest' cluster. This does not mean this cluster is not important

The process of clustering will naturally evoke discussion around the newly formed clusters. The discussion can lead to a conversation about which cluster is deemed the most important. The most important clusters can be labelled with a green sticker or other marker. The most important clusters can then be fed into the next stage of the co-creation process. As a facilitator, you can formulate design questions based on these clusters to aid in the co-creative design assignment.

Case example:
In the final workshops concerning the Flying-V's galley, a so-called purge was conducted after the initial energiser activity. The facilitator guided flight attendants to brainstorm and note down their spontaneous general thoughts associated with working in a galley. They were given three minutes to do so.
Next, the facilitator redirected the participants' focus towards the positives - aspects they appreciated about the galley environment. This brainstorming round was also set for three minutes. After this, a similar exercise was repeated, this time focusing on the negatives - aspects they did not like about the galley environment.

This iterative brainstorming served as a warm-up and provided a pool of ideas that could be revisited later in the workshop. While participants were busy with their current brainstorming, the Post-It notes from the previous instruction were gathered and spread out on a table by the facilitator. Participants were then invited to gather around the table, read the notes aloud, and stick them on the wall.

With the help of facilitators, clusters of similar or related ideas began to form. The participants engaged in discussions around these clusters and identified those they considered the most important. These were 'workability' and 'sound'. From these discussions, a set of 'How to' questions was developed, representing the main challenges to address in the next part of the workshop. In this particular workshop, the two questions formulated were:

1. "How to create a galley that enhances a good working experience?" and

2. "How do we improve galley acoustics?"

Fig. 93: Clustering the in the brainwriting stage

Break

STEP 4: Workshop Creating the New Context

Materials Needed:

- Arts & Crafts Materials
- Floor plan
- 3D 'make tools'
- Laptop
- Facilitator: HMD

This stage is where new ideas are created and materialised. Before this can happen, it is crucial to prepare the room and workspace and organise all the necessary items. Participants should be provided with various materials—like 3D printed objects, cardboard, foam, wood, plastics, and more—and encouraged to build their own version of the to-be-designed object, assembling and rearranging components much like one would with Lego or Tetris blocks. The construction site for the building should also be prepared and ready to use as soon as participants are in this workshop phase.

To foster interaction, it is beneficial to have at least two participants work on the same project together. If the total group is split into smaller groups, ideally, one facilitator per subgroup would be beneficial to be vacant for questions, advice and tips. When working with more than one facilitator, it can be helpful if one of them is documenting the session with pictures, notes and videos. This facilitator can also prepare the XR world whilst the participants are designing. However, the novelty factor of using XR might be lost, and participants may get distracted when only one person is wearing an HMD.

Additionally, to explain the assignment, a small design brief can be printed as a backup for the facilitator and participants to fall back on if necessary. A small reminder of the design questions can also be asked during the session.

Upon completing the design phase, participants, if working in subgroups, can present their design work to the other group(s) and facilitator(s). Alternatively, they can present their work directly to the facilitators. Facilitators have observed that presentations shared between groups—effectively expert to expert—tend to stimulate more robust exchanges of ideas and discussions. As a facilitator, it is important not to pass judgement and to ask open-ended questions about why, how, and what participants have designed. Ask questions about what underlying thought processes and motivations motivated these design choices.

Case example:
In the creating the new context phase of the workshop, participants were first shown three videos as a source of inspiration for creating the new galley in the Flying-V. Two of these videos concerned the Flying-V, and one contained future concepts in aircraft design. In a final PIW, it was decided to bring the XR world and the physical world as closely as possible together within the given time frame of the project. Two 900 mm x1800 mm sheets of paper, each containing half of the top view of the cabin of the Flying-V on a 1:20 scale, were joined together on two tables. The model took around 20 minutes to build with two facilitators. The model included fuselage parts of the Flying-V alongside 392 passenger seats (which were not all utilised). Additional blocks serving as galley elements and additional mannequins scaled to represent average Dutch female and male height between the ages of 20-60.

The scale of the model made it possible for participants to walk around the model and move blocks as they wished to create their ideal galley. One facilitator guided these participants whilst they created their preferred galley. Meanwhile, on the other side of the room one facilitator with two flight attendants were creating their ideal galley in XR using a collaborative session in Gravity Sketch. The flight attendants instructed them where they would like things to go and the facilitator aided them in their ideas and creations.

After the designs were completed, participants each held a small presentation presenting their ideas to each other. This led to ideas being elaborated on.

Fig. 94: Laying out the pink trash compartments

Break

Fig. 95: Discussion of the layout aided by the model

STEP 5: Workshop Immersing in the New Context

Materials Needed:

- Floor plan
- 3D Physical Model & 'Make Tools'
- Multiple HMDs (depending on the number of participants)

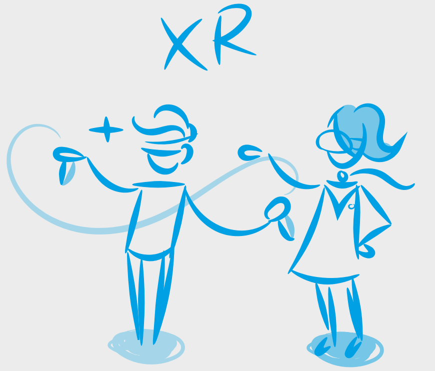
After creating the new context, you are now ready to immerse your participants into the new context with XR. Before this can happen, you must have your HMDs powered up and connected to your program of choice, preferably Gravity Sketch. To create the shift from physical to XR, you must have the exact representation of what was made in the physical world in the virtual world. This can be modelled by one of the facilitators in the break after the "creating the new context" phase has taken place or by an assistant who simultaneously is modelling while participants are creating. However, the latter option might be distracting for the participants while they are designing themselves.

For the XR modelling to be as efficient as possible, your virtual objects need to be set up beforehand so that, for this stage, it is only a matter of dragging, dropping and duplicating objects. A virtual stash of editable objects should be created before the workshop that represents the physical objects used in the former part of the workshop.

Upon successfully replicating the physical world in the XR realm, several additional steps are required to immerse the participants in the XR environment. For a unified viewing experience, all participants must log into the same virtual environment. Ideally, this is done by the facilitator during the break connecting each headset to the same virtual room.

Subsequently, each viewport should be calibrated to ensure a consistent scale and positioning of objects. This procedure guarantees that all participants observe the same virtual objects from their respective HMDs. Ideally utilising point cloud data could automate this step. However, as of the time of writing, this function is not yet available in Gravity Sketch for collaborative sessions. In order to calibrate all headsets to have the correct viewing angle and scaling it is recommended to first make sure the scale is set to the correct size, so, for instance, 1:1 for each headset.

Secondly, a reference object in the physical world can be chosen to pair with the XR world. This can be anything from a tile on the floor to an object on the wall. Preferably this object has lines that collide at a 90-degree angle to make referencing more precise and easier.



Case example:
During the coffee break, one of the PIWs, a facilitator, quickly copied the physical designs of the participants to XR by mocking up the design in Gravity Sketch using an Oculus Meta Quest 2 HMD. This was done by using 'pass thru mode' where the facilitator wearing the headset could still see the physical surroundings while wearing the HMD. This allows for a mixed reality mode blending virtual and physical elements together.

After modelling this, the facilitator connected the other HMDs to the same virtual room by logging into each HMD through the TU Delft EDU network provided through the XR Zone in the library. This enabled multiple users to join the same room in real time. A tile on the floor was used to mark an origin point in the physical room for all the HMDs to be aligned to. This was necessary to give participants the correct orientation point. While exploring the virtual world, new ideas in the participants emerged, and the imagination of participants was triggered to suggest additional concepts.

In another PIW, participants took turns exploring the XR world. This lets them piggyback on each other's ideas while the HMD rotates between participants. This created a sense of mystery and excitement in participants not wearing an HMD since they could only see the reactions and hear what the participants wearing HMDs were reacting to.

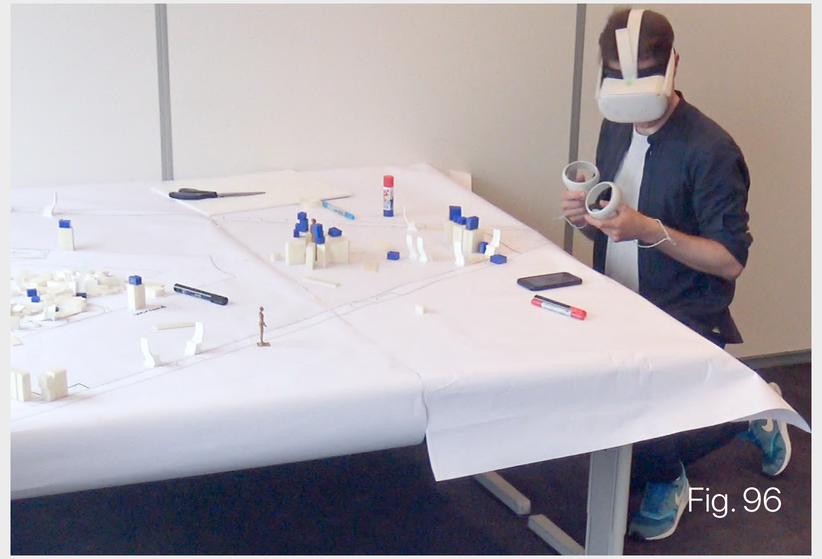
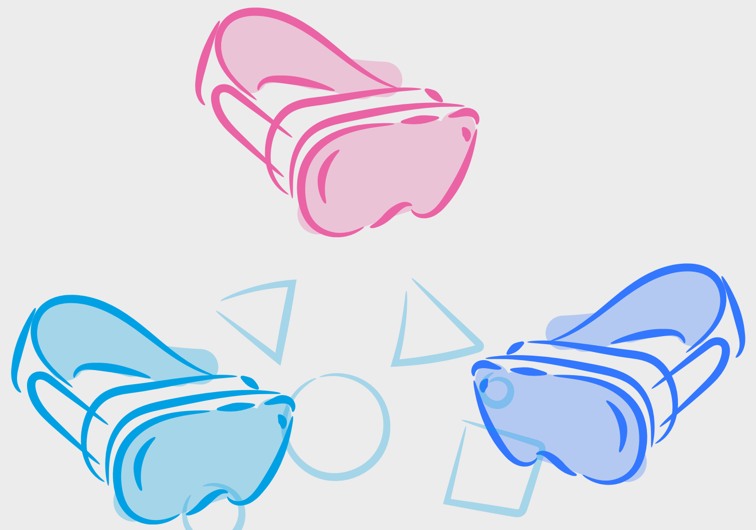


Fig. 96: Copy of Fig. 44: Laying out the XR design



STEP 6: Workshop Evaluate

Materials Needed:

- Questionnaire online or on paper

Evaluation within the co-creation process can be done on two levels: the evaluation of the design deliverable emerging from the co-creation session and the evaluation of the co-creation session itself. The evaluation of the co-creation itself can be split into evaluation by the participants and evaluation of the facilitators. The latter will happen post-workshop.

Firstly, within the context of the PIWs, evaluation began as soon as participants entered the 1:1 scale XR environment. Additionally, feedback exchanged during the presentations of individual designs also constituted a key evaluation phase. These assessment steps can occur either within the virtual or the physical world, thus allowing participants to be either immersed or not. Evaluating the design within the virtual environment is, however, particularly valuable since this brings a new opportunity to view things from other perspectives and has, in the PIWs, been shown to trigger new ideas among participants.

Secondly, evaluating the overall co-creation workshop itself can be achieved via post-session questionnaires. These can yield important insights into the session as a whole and offer guidance on how to refine and improve future co-creation workshops. It is best to plan some time for these at the end of the workshop so the participants' memory is still fresh.

Case example:
In the final PIWs, an evaluation was done by commenting on ideas the participants had come up with after they had presented their designs after the "design the new context" phase of the project. These ideas were first discussed using the physical 1:20 model. Then the XR 1:20 model. Discussions were initiated by the facilitator, asking questions such as: "Why did you choose to place your work surface here?" or "How do you access the bar area from the back of the aircraft?" After immersing into the 1:1 scale XR model, each participant evaluated the design on a life-sized scale. As mentioned before, as participants took turns evaluating the design on a 1:1 scale in XR, they commented on things that they would like to see improved or added to the design. In other words, the evaluation led to live design iterations that made for immediate adjustments. Each participant took turns in evaluating what the previous participant had done before them.

Fig. 97: Participants awaiting the results of the facilitator and one participant being immersed in XR

STEP 7: Post Workshop Reflect

After completing the co-creation session, it is recommended to take a step back and reflect on the overall process, outcomes, and experiences. Reflecting allows for a deeper understanding of what worked, what didn't, and why, thus providing insights for future sessions. In one of the PIWs, it became clear that it is recommended to have a second facilitator acting as an observer. Observation and note-taking can considerably help with the reflection part after the workshop. Consider the following points:

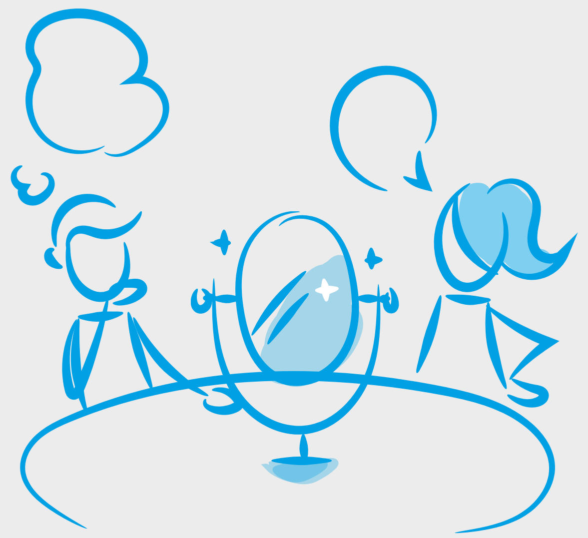
- Evaluate the design deliverables: Assess the results and consider how well they meet the session's objectives. Did they lead to fresh perspectives and ideas?

- Reflect on the co-creation session: Consider the dynamics of the session and the group, the effectiveness of the tools used, and the overall participant experience.

- Gather feedback: Analyse the feedback from the questionnaire provided at the end of the season. Optionally, feedback could also be provided through a post-workshop discussion or conversation with participants.

- Document and share the outcomes: Share the session results with the relevant stakeholders. This ensures transparency and allows everyone to see the value of the session.

This reflective process should serve as a learning experience, providing closure to the co-creation session and setting the stage for improvement in future sessions.



Case example:
In the final PIWs, questionnaires were used post-workshop or in the final stages of the session to gauge the participants' experiences. Unfortunately, only partial results could be processed on time to inform the next co-creation session. The results that could be processed did, however inspire minor tweaks for the next session or as a feedback loop to see how well sessions were received. Minor adjustments were, for instance, aiding in idea generation at certain points and making sure models were viewable correctly to prevent dizziness.

Desirability:
The benefits of XR are apparent and, as stated earlier by Deloitte: " The future growth of XR will in part dependent on repeat usage and 'in simulating work experiences and visualising enterprise and industrial-scale systems' This is certainly applicable in combination with co-creation. The proposed design method in this thesis, XR+, meets these requirements. Co-creation workshops with KLM cabin crew highlighted the unique strengths of both traditional co-creation and XR. The fact that participants found physical blocks intuitive and the immersive environment of XR stimulated creativity indicates that the method is desirable for those involved in design processes and can apply to a wide range of other topics and design cases. Furthermore, with the Flying-V aircraft as a case study, the benefits of a co-created design approach have been demonstrated, proving its desirability for complex projects.

Feasibility:
The five workshops (+ pilot workshop) served as practical tests for the method, and each iteration refined the integration of XR+ into the co-creation methodologies. Participants found it feasible to build initial concepts using physical objects and then further explore these concepts in an immersive XR environment. The success of these workshops proves that the method is not just theoretical but can be effectively implemented in real-world settings. Furthermore, DLR has the capabilities and resources to continue to host these types of co-creative sessions. A small investment on the side of DLR is needed for additional HMD equipment, ensuring there are enough HMDs participants and that they are wireless as opposed to the wired versions now. From the authors' personal communication with one of the bosses at DLR, this should not be an issue.

Viability:
As XR equipment becomes more common in society, so will the viability of adding XR+ to the design of the existing design process toolbox. By blending traditional co-creation with XR it can result in diverse idea generation, making it attractive as a design tool for discovering innovative solutions. Given the success of its application in the Flying-V case study, it is reasonable to expect that XR+ will provide benefits in other future design projects.

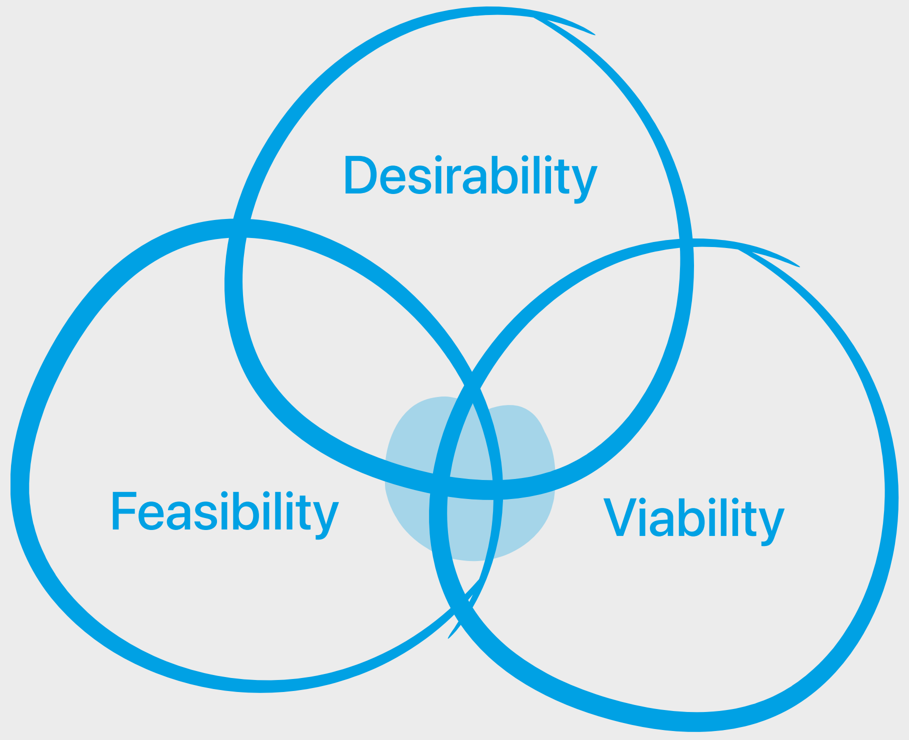


Fig. 98: The intersection of desirability, feasibility and viability

Discussion & Recommendations

8

8.1 Introduction

All instances of the PIWs brought forth considerable learning. The sessions provided fresh insights and concepts. In other words, new ideas of the diverse ways the galley space could be utilised were discovered in the co-creative sessions. However, the first time working with flight attendants showed that the workshop needed to be tweaked. Unlike designers, these professionals weren't used to thinking creatively about aircraft spaces in their day-to-day work, so the way they interacted with the process was different. Consequently, adjustments in the following workshops were deemed necessary.

Interestingly, this initial challenge wasn't present in the later sessions. It is possible that this was because the facilitator(s) got used to this new kind of session and figured out the best or most appropriate ways to interact, or that the different flight attendants made a difference or a combination of the two former factors.

8.2 Practical Applications

Practical Applications: The co-creation method presented in this thesis offers a diverse range of practical applications that could span several industries. Initially developed within the context of designing a galley for the Flying-V its scope could go well beyond the aerospace industry. The method is particularly potent when a collaborative, creative, and user-centred approach is required, making it applicable to other fields in transportation design like automotive and rail, but also architecture and urban planning.

For example, railway industries could use this approach to design more user-friendly interiors for their carriages, while urban planners or architects could harness it to better shape community spaces and interiors in accordance with residents' needs and wishes. The specific combination of physical objects and XR makes it suitable for the ideation and prototyping stages of the fuzzy front end of design where things are still uncertain and undefined. It can provide scaffolding and experimentation room for this ambiguous stage of the design process.

8.3 Benefits

There are numerous benefits associated with this co-creation approach, including its potential to facilitate a richer, more diverse dialogue around design problems. The use of the physical objects has a near to zero learning curve as found in the PIWs. The hands-on approach can lead to many design ideas that are deemed relevant by the participants as was the case in the fourth PIW. This method encourages active participation from all participants involved and can be a 'playground' not only for end-users but also for design professionals and other stakeholders fostering a democratic and inclusive design process. As a result, the diversity of ideas and perspectives that emerge can lead to more innovative and user-centric outcomes, which eventually benefit the end-user.

The integration of XR tools literally adds a new dimension and can significantly enhance participants' imagination and spatial understanding as stated by participants of the PIWs. The latter is especially beneficial when designing physical spaces or objects. The immersive nature of these tools can also make the design process more engaging and enjoyable for participants, fostering a greater sense of investment and ownership over the final outcomes as quoted by some of the participants in the PIWs.

8.4 Limitations & Challenges

Despite its potential, the co-creation method is not without its challenges. The technical requirements, both in terms of hardware and software, may present a barrier to entry for organisations due to cost or technical expertise required. Also, creating the physical 'make tools' requires considerable time investment accounting for technical difficulties and failures. However, for DLR the method would be realistically implementable since the resources and skills necessary are nearly all already in house. For the creation of to scale floor plans a plotter would still be necessary.
Furthermore, the success of this method is highly dependent on the skills of the facilitator. A skilled facilitator can manage group dynamics, encourage participation from all parties, and guide the design process effectively. However, if these skills are lacking, the process may become unproductive and less engaging. This is something the author had to learn along through the PIWs. The ability to model what participants had made quickly in XR was found to be, especially in the first PIW, a stressful task.

Stakeholder acceptance could also be a challenge, especially in more traditional or conservative contexts. This approach requires a willingness to embrace innovative methods and technologies, which may not always be present. Additionally, because of the novelty and versatile uses of XR there is a risk of over-reliance on technology. This could lead to the undervaluation of traditional design methods and underappreciation of the nuances that come from real-world interactions. Hence a healthy balance of both physical and XR is required, this can vary from session to session.

8.4 Ethical & Social Implications

It is important to ensure that the process is inclusive and accessible to all participants, regardless of their background or level of technical proficiency. This might involve providing additional support to some participants with the technology. A warning of potential motion sickness should be given prior to using XR.

From a privacy standpoint, if documenting the co-creation session in any way, through either video or audio, participants must be informed of this and give their consent regarding this. During the PIWs this was asked before starting the session. All participants agreed to be recorded. Furthermore, there must be protocols in place for managing and protecting any data that is shared or created during these sessions. This is especially relevant given the potentially sensitive nature of the designs that participants may create. However, since DLR is a government funded agency and most knowledge is open to the public, this would only apply for private companies.

8.5 Future Directions

Paradoxically this technique relies both on high-tech and low-tech to work. The author has argued that each technique has its own strengths and weaknesses. The power lies in bringing the two closer together. A direct link between the physical and virtual objects would greatly enhance and streamline the process. Similar options like this exist but rely on QR codes to work or are not very flexible in what can be made with them. Improving on this could make the transfer from physical to virtual more intuitive without needing a facilitator to model the elements during the co-creation session.

As technology evolves and bigger companies like Apple are also getting involved in XR, there will also be opportunities to incorporate new, still unforeseen, developments into the process. Haptic technology could provide tactile feedback in the virtual environment, creating an even more immersive experience and perhaps eliminating the need for the physical part of the co-creation session. However, the importance of real-life nuances can not be overstated.

Finally, with the ongoing global shift towards remote and flexible working, there is a clear opportunity to explore how this method can be adapted for remote collaboration. Gravity Sketch collaboration already works remotely, however, remotely working with physical 'make tools' could pose a challenge. However, it's worth noting that, based on current experiences in PIWs, the author would argue that physically bringing participants together leads to the most fruitful results. More research on this topic would, however be needed.

Personal Reflection

9

9.1 Reflection on the process

This final section will be a reflection both on a process and results level.

Knowledge obtained

I had a few learning objectives before starting the project, and I am pleased to say I ticked them all off during my graduation project. The first one is how to use XR. I had no experience with XR before starting my project and had only tried a VR headset a couple of times at either stores or exhibitions. Nor did I know anyone who owned an HMD. Since this was still so unfamiliar to me, it sparked my interest, and I discovered a whole new (virtual!) world. It was, at times, hard and, at times, fun. The former was when the equipment did not work properly, or adjustments had to keep being made, the latter was when it did work and when I got to see people's reactions when trying it out. I'm happy to say I now feel quite comfortable using XR (for a limited time at a time!) since I understand the technology and capabilities better. The start of the project was quite intimidating since I had no prior knowledge.

This was similar for co-creation. I had been part of a co-creation workshop but only as a participant. I had never facilitated a workshop in my life and was curious to learn how to do this because of the obvious benefits it yielded. You could say that starting with two topics you are unfamiliar with is maybe not the best strategy, I knew little about XR and co-creation. However, someone at the TU once told me that your graduation project is the last opportunity for you to experiment and learn in an academic setting, only you get to pick and choose! I could have chosen topics I am more familiar with and confident in, but in the end, although intimidating at times, I'm glad I chose the unknown.

I can now, with confidence, say that I know how to host a co-creation session whilst involving XR. There are for sure bottlenecks to using this combination, but with the knowledge I gained in the last couple of months I feel like these challenges are more manageable.

Methods used:

Since this was an exploratory research, I had to partially develop my own method. Of course, grounded in design methods which I had previously learned. However, since the combination of co-creation and XR is still a relatively unknown domain, there was no clear method I could use to combine the two. Furthermore, discovering the method and figuring out how the two fit together was the biggest part of the thesis. The iterative cycles of testing and prototyping through the co-creation workshops led to results that can be considered a method or tool that can be added to the existing design process and methods. The double diamond, although not explicitly mentioned in my thesis, of diverging and converging inspired my iterative process. I tested out a lot of things to see what worked and what didn't work. From there, I could converge the results and feed them into the next iteration, and so on. It would be great to see more combinations of XR and co-creation in the future, and I'm sure there will be more since this is only the beginning of the spatial computing era.

Communication with stakeholders and supervisors:

Since DLR is based in Hamburg, I had to move to there to conduct my thesis. This meant all supervisory meetings from the TU Delft side from the start of graduation had to be conducted online. This did, however not have any negative impact at all. I would say there were highly efficient. At DLR, I could always spar with my supervisor during the week if this was deemed necessary, and this was a great privilege to be able to do so. These (online) interactions were always enjoyable and interesting and I would like to thank all of my supervisors for thinking in a very proactive way and advising me on my progress. The meetings were always a great opportunity to get feedback in general but also in times when things got very experimental to see what the next best strategic steps would be. I was encouraged to make my own decisions since I was the lead designer of the project. I could sometimes find this hard because of the uncharted territories we were embarking on. However, once I made the decision to focus on the combination of physical and virtual elements, it made sure I could see the path in front of me clearly again. After the initial tests at KLM I was greatly helped by KLM in planning further co-creation workshops which greatly benefitted the project.

Project Management:

Project management has never been my strongest point, yet for graduation, it is mandatory to hand in a project planning at the start of the project. This forced me to think clearly about what it was that I wanted to achieve and when. I must say it was sometimes hard to stick to the planning due to the flexible nature of the project. The midterm was a good grounding moment to see where I stood and to reflect on further planning. The same was true for the green light meeting.

The beginning of the project was quite straightforward in that a lot of literature research was done. Bringing the research together was a big task since there was a great amount of information available. However, I kept discovering new insights and found it hard to 'stop' the research phase and get into the design phase because new information was deemed relevant.

Recruiting flight attendants was an ongoing process, but I was also afraid of recruiting them too early and not having anything to show. However, once I felt I was ready to test, it took a little while to get things going. When things really took off, the end of the project was already approaching. In hindsight, I would have stopped the literature research a little bit earlier and recruited a little bit earlier to spread out the great deal of work which was now done towards the end. The mandatory planning did however provide a great deal of peace by removing uncertainties and knowing what I needed to do when.

9.2 Reflection on the Results

The assignment:
I'm glad I could find an assignment that fit my personal wishes so well. As mentioned, moving to a new place and starting to work on topics to which I had little to no prior knowledge was at times intimidating. Luckily at DLR I was provided the freedom and time to research these topics and get familiar with them. Working with end-users is something I have always wanted to do and that I found out is very enjoyable to do. I really liked the fact that this assignment perfectly balanced the technological side and the human side. Both are topics I am interested in but would be difficult for me to focus on just one. I like to think of myself as a designer that is interested in people and technology, so this assignment fit that description perfectly. Too much of either would be more of a challenge to deal with. I did find myself sometimes getting lost in the details or literature, especially at the beginning and had to remind myself of the goal I was pursuing.

At times testing with KLM cabin crew felt like something unachievable. Partially because I was based in Hamburg and partially because I could not get hold of the right people for a long time, this is when doubts slipped in and time slipped away. I kept telling everyone I was going to test with flight attendants when in reality, I was worried if this would ever happen. Luckily after having found the appropriate entry through a contact of my Chair, things got underway. It was then I felt the assignment got 'real', and it was not just something I thought up in my head. Having to test and co-create with actual flight attendants was a delight, and although preparation could be hard and stressful at times, it was always worth the prior hard work.

The results:
I'm pleased to say that I'm happy to have discovered something in the combination of XR and co-creation. From the very beginning, I felt that there was a lot to explore in these two topics. DLR felt the same way, hence writing a paper on applying XR in the early design process. Whilst conducting my thesis at DLR, designers already implemented some of the methods used in my final result, which is a humbling fact and a testimony to being on the right track, something I am grateful for. Because I was conducting my thesis at DLR, some of the staff could implement my findings, work or ideas 'live' into their process. At times I felt that I would not have anything new to show towards the end of my thesis. However, I am pleased with the results since some of them can hopefully be implemented to make the design process that little bit better in some way and to build and expand upon in the future hopefully.

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