Aalto University
School of Arts, Design
and Architecture

Difficulties with understanding and presenting custom-made furniture design solutions.

Elde Siilbek

Collaborative and Industrial Design

Department of Design

Aalto University School of Arts, Design and Architecture

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Author Elde Siilbek

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Abstract

This thesis delves into the difficulties arising during the design of bespoke furniture. While advancements in interior design education, services and technologies have enhanced the custom-made furniture ordering process, challenges persist. This study delves into the complexities arising during the design of bespoke furniture, shedding light onto spatial imagination constraints, hidden requirements, and miscommunications among stakeholders.

Traditional 2D presentations, laden with limitations, inspire the exploration of augmented reality (AR) and virtual reality (VR) technologies as potential transformative tools. The study, driven by my firsthand experiences as a furniture designer, investigates difficulties in presenting and understanding spatial plans. Two central questions guide the research:

1. The nature of challenges in comprehending and presenting spatial solut ions
2. The potential role of AR and VR technologies in alleviating these challenges

This study unfolds findings, such as hidden requirements, mistargeted design presentation tactics, lack of interactions and independence, among others, and addresses the importance of these issues to prevent loss of resources and dissatisfaction. Alongside, AR and VR technologies emerge as potential avenues to integrate into the design service by offering immersive experiences in spatial understanding.

The study's implications extend to validating the need for customer-centric and functional design, exploring the potential of AR and VR technologies, and emphasizing the importance of feedback communication. The study's broader perspective highlights the intertwining concepts from diverse domains, that emphasize the need for effective probing mechanisms in requirement engineering structure and innovative presentation techniques.

Points for intervention lie in understanding customer needs, restructuring design presentation methodologies, and reframing feedback obtainment. This research contributes to transforming the custom-made furniture design landscape, that foster collaborative, informed, and satisfying design experiences.

Keywords furniture design, design presentation, spatial imagination, requirements engineering, augmented reality, virtual reality, stakeholder experience

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1 INTRODUCTION

The need to design and furnish spaces is a part of everyone's life at one point or another. Throughout different spaces of shelter and living situations, the need for custom-made furniture solutions always remains to accommodate individual preferences. The process for ordering custom-made furniture has been improving with the development of interior and furniture design education along with related services and technologies (Pardes, 2017; B. Elliott, 2022; "Customisation", 2020)

While custom-made furniture is designed and built to meet the unique needs and preferences of an individual or a group, there are several potential problems that may surface during the process of designing custom-made furniture. These problems can be related to spatial imagination skills and hidden requirements for furniture. The issues can thereby transpire miscommunication between parties, including designers, managers, producers, and furniture installers. Customers that order bespoke furniture designed and produced specifically for their spaces, are presented with spatial design solutions from interior designers, furniture designers, and producers (discoh, 2017). The presentations of interior and furniture design solutions consist of multiple 2D and 3D visual elements, such as plans, models, and samples; furthermore, the use of virtual and augmented reality technologies in design presentations have begun to emerge (Slenske, 2018). When it comes to presenting interior and furniture solutions, however, fully understanding how room plans and material samples come together before real life experiences can be difficult. The level of spatial imagination varies depending on how familiar customers are with interior and furniture design practices, the ever-changing array of materials, and awareness of their own needs and requirements. Additionally, clear cognitive understanding of living among planned furniture, including aesthetic and interactive aspects, can be affected by the quality of design presentations introduced by designers. Therefore, misunderstandings between parties and unawareness of individual requirements in aforementioned conditions can lead to unconscious expectations and unsatisfactory outcomes. This in turn can result in loss of resources such as money, time, materials, and products, but also damaged relationships between customers and service providers.

During my years of practice as a designer for bespoke furniture, I have gained experience with witnessing difficulties in understanding and presenting spatial design solutions through visual means, such as plans, 2D and 3D models and samples. This experience stands as a motivating factor in this research. It is important to research the issues and reasons for miscommunication between parties to prevent the loss of resources, and feelings of dissatisfaction. Thus, this research is focused on surfacing and explaining the problems that surround presenting and understanding spatial plans and custom-made furniture solutions before furniture is built.

While some visual elements in conveying design proposals, such as plans and models, are more established and prevalent, the use of virtual reality and augmented reality (VR and AR, respectively) is becoming more relevant as a design communication tool (S. Elliott, 2022). The prevalence of VR and AR technologies in interior design is in an emerging and moldable phase, which allows exploration of their functional uses within furniture design services. The idea of using AR and VR technologies can provide multiple uses in the process of designing custom-made furniture. Therefore, an evaluation of VR and AR technology will be conducted where the primary goal is to evaluate how these technologies function in response to issues in spatial communication.
To access insights on these topics, the research is focused on two questions:

RQ 1. Which difficulties arise with understanding and presenting spatial and furniture design solutions?
RQ 2. Could additional use of AR and VR technologies help prevent these difficulties?

The main objective for this study is to discover and explain the issues to improve interior design services. It is important to encourage interior and furniture designers to practice spatial design collaboratively along with the stakeholders by eliciting their needs in a clear manner and meeting their requirements. Through collaborative process, the customer is allowed to take an active role in the design process of their spaces and assure satisfaction after receiving the order. It is crucial to bring attention to problems in communication between the customer and furniture designer to ensure the customer is well informed to confidently take responsibility for their choices. It is also important for interior designers, and customers as co-designers, to be aware of issues in visual presentation practices to avoid misunderstandings.

2 BACKGROUND & RELATED RESEARCH

"As practitioners, we solve the design problems for humans who use and inhabit the space by considering their needs, whether functional, social, psychological or environmental by understanding how to use research to help identify and clarify the relationship between human behavior and the built environment."

(Perolini, 2011, p 172)

The background and related research for this study focuses on three areas related to furniture and interior design which are linked to difficulties with presenting and understanding spatial solutions: 1) common and emerging spatial design practices currently used to communicate spatial solutions; 2) the comprehension and understanding of design presentations through vision and cognition; 3) exploration and application of stakeholder requirements engineering concept.

2.1 COMMON AND EMERGING PRACTICES TO PRESENT SPATIAL DESIGN SOLUTIONS

Familiarity with current practices and the process of ordering furniture lays groundwork to navigate the realm. The backbone for ordering interior or furniture design is a *design proposal*. A design proposal is widely known as a document or multiple documents, that outlines the design solution for a specific project or problem. It presents a detailed plan about addressing the requirements and objectives of the project and explains the key features and benefits of the proposed design. According to Pile (1995, p 130) the first correspondence between the designer and the customer outlines the project scope, schedule, and budget. After an agreement has been made, the project moves on to collecting customer requirements, developing, and showing an initial design, after which, in cooperation with the customer, a detailed design is completed. At this point a design presentation needs to be made, the budget needs to be updated and detailed, and confirmation by the customer is necessary to call for action (Pile, 1995a).

The purpose of a design proposal is to persuade a customer to accept the proposed design solution and move forward with the project. Additionally, the information is likely constructed by industry standards and best practices. A design proposal should be well-organized, visually appealing, and clearly communicate the design vision and objectives. The proposal for custom-made furniture typically includes the following elements presented in Table 2.1 ("How to Write an Interior Design Proposal," 2022; Chavez, 2022; Qureshi, 2021).

I have divided the table into two columns, practical and spatial, to illustrate the nature of different elements, with aims to separate and show which elements this study is focused on. The nature of practicalities in this table encompasses organizational elements, which have a management and planning focus. Spatial design column emphasizes the elements in a proposal that have a main focus on design in terms of building and creating the furniture.

Design proposal elements	Practicality	Spatial design
Project description: a detailed description of the project goals, objectives, and scope, including the client's requirements, project timeline, and budget.	yes	no
Requirements: a process which focuses on the customer's clear communication of needs and wishes in terms of preferences, tastes, and ultimate goals.	yes	yes
Design concept: a visual representation of the design concept, like sketches, renderings, and/or mood boards that showcase the design direction and aesthetic, sometimes with the help of work examples or portfolio.	no	yes
Space planning: a detailed layout of the room with multiple views or section cuts, including furniture placement and traffic flow.	no	yes
Furniture specifications: detailed specifications for each piece of bespoke furniture, including dimensions, materials, finishes, and other relevant details.	no	yes
Project budget: costs of the project, including materials, designer's work, production and installation labor, and any other expenses.	yes	no
Timeline: a timeline for the project duration, including milestones and deadlines.	yes	no
Terms and conditions: the terms and conditions for the project, including payment schedule and warranty information, expectations to the customer.	yes	no

Table 2.1. Synthesized design proposal structure. (Pile, 1995; "How to Write an Interior Design Proposal," 2022; Chavez, 2022; Qureshi, 2021).

Pile (1995) explains that the project scope and size determine which of these steps mentioned in Table 2.1 are required. Spatial development of a large house with multiple spaces may require all of the 'spatial design' elements explained in Table 2.1 to run the project successfully.

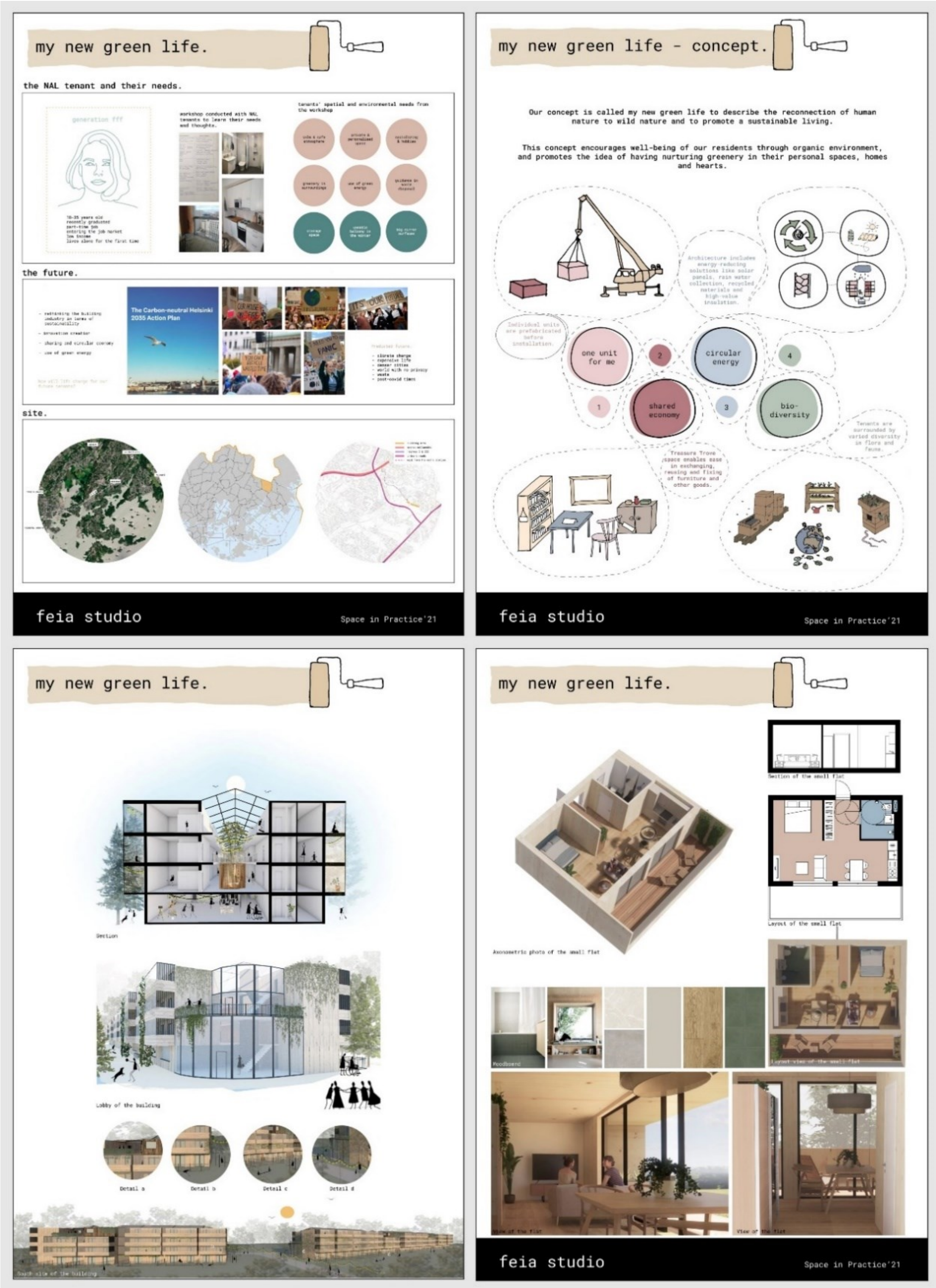

Figure 2.1. Example of spatial development for a housing complex. (Siilbek et al., 2021)

Images in Figure 2.1 depict a spatial part of a design proposal for a housing complex, which includes requirements (image on top left), design concept (image on top right), space planning and furniture specifications (images on bottom left and right).

A simple piece of furniture may not require so many elements and sometimes a plain design presentation, such as in Figure 2.2 can suffice. This example does not include any other parts of a design proposal, but merely furniture specification.

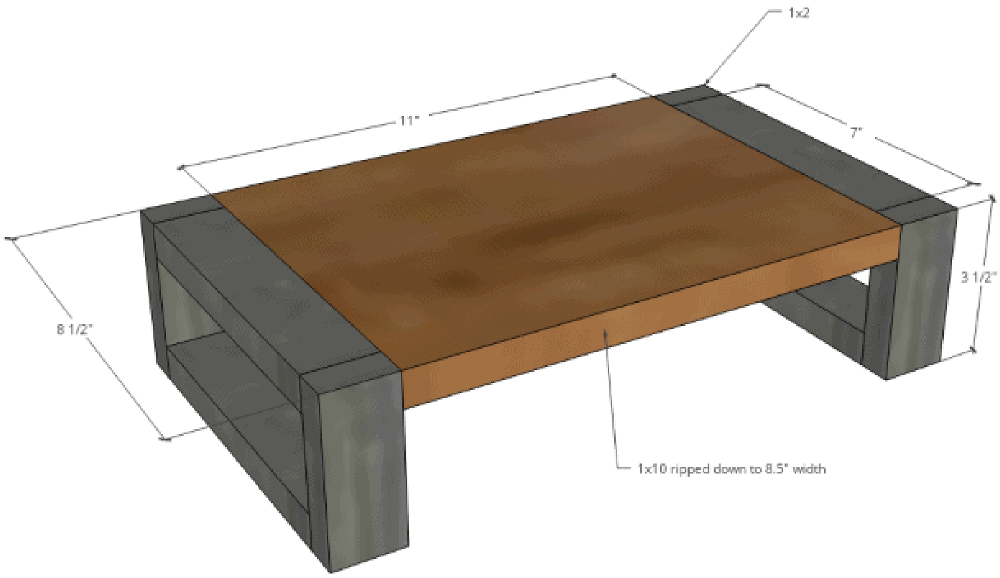

Figure 2.2. Example of simple furniture design proposal (Schlachter, 2020)

Design concept, requirements, space planning, and *furniture specifications* in Table 2.1 are steps which function as 'spatial design' in this study, and where the main contour of this study is drawn. The 'practical' steps such as budget, timeline, terms, and conditions, are not the focus of this work.

Relying on Pile's (1995b) checklist of design steps and personal experience from industry practices, the 'spatial design' process and communication between the designer and the client follows the subsequent steps depicted on Figure 2.3 as a process flow diagram. The diagram describes which processes are involved in the 'spatial design' part of the design proposal and explains the back-and-forth communication between the stakeholders to build the solution.

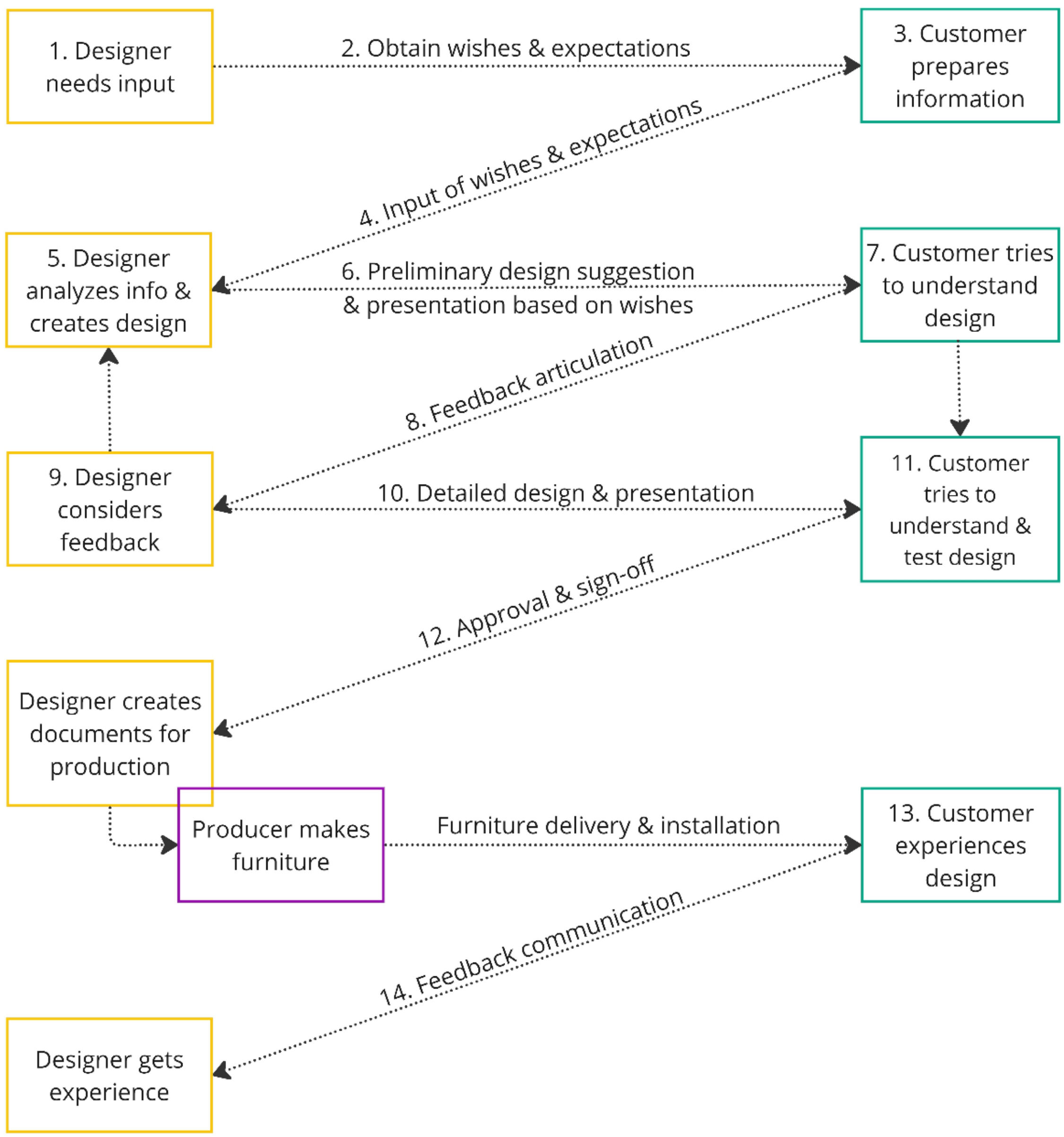

Figure 2.3. Spatial design process and communication.

It is the designer's responsibility to convey spatial design to a customer. But which aspects do designers need to follow to allow the customer to understand, analyze and evaluate their new space in a clear manner? Pile (1995b, p 33) explains that *"in order to analyze and evaluate a proposed design, it can be viewed in terms of three closely related qualities: function, structure and materials, and aesthetics."* He explains that *function* is the term to describe the practical purposes of the design that it was created for. Besides the primary functions the furniture was created for, it must support multiple secondary functions. For example, in addition to providing seating, which is a chair's primary function, the design must satisfy the need to move the chair, keep it clean and maintain. *Structure and materials* are a related quality to function but can be separated from functionality by values like durability and costs. These values are affected by the quality of materials and workmanship. *Aesthetics* can be more difficult to analyze and evaluate as the criteria cannot be explained in a logical way and can be discharged as *"a matter of taste"*. In spite of that, he claims that *"better is distinguishable from worse"* even if the aesthetic design does not fit into a specific interpretation of beauty (Pile, 1995b).

Communicating spatial design requires these qualities to be conveyed in order to explain and understand spatial plans (if the flat is unfinished or if the customer doesn't yet live there), furniture design and placement. To convey these qualities, methods such as sketches, renderings, mood boards, layout of the room, views and section cuts, dimensions, material specifications, and finishes, to name some, are incorporated. This is a crucial part of a design proposal as it introduces the solution in a visual manner. The customer is expected to view the presentation and give feedback until final sign-off. The methods, illustrated by images in the following paragraphs, give an overview of design presentation tools used to convey spatial and furniture solutions. (Kovalchenko, 2019; "How to Create a Professional Interior Design Presentation", 2021)

2.1.1 HAND-DRAWN SKETCHES AND DOODLES.

This commonly practiced method is used to put ideas on paper swiftly by either drawing, pointing, marking, and writing, amongst other things, as illustrated in Figure 2.4. It is a helpful tool alongside verbal explanation by allowing to visually depict what is being explained. Doodling can be used at a planning or conceptual level for preliminary design as it doesn't have much visual value compared to many other methods used in modern interior and furniture design domains. The method is exercised by using a two-dimensional paper or other flat surface where the doodler uses either orthographic or perspective views to draw. Sketches are helpful to plan furniture functionality and support discussions that elicit requirements.

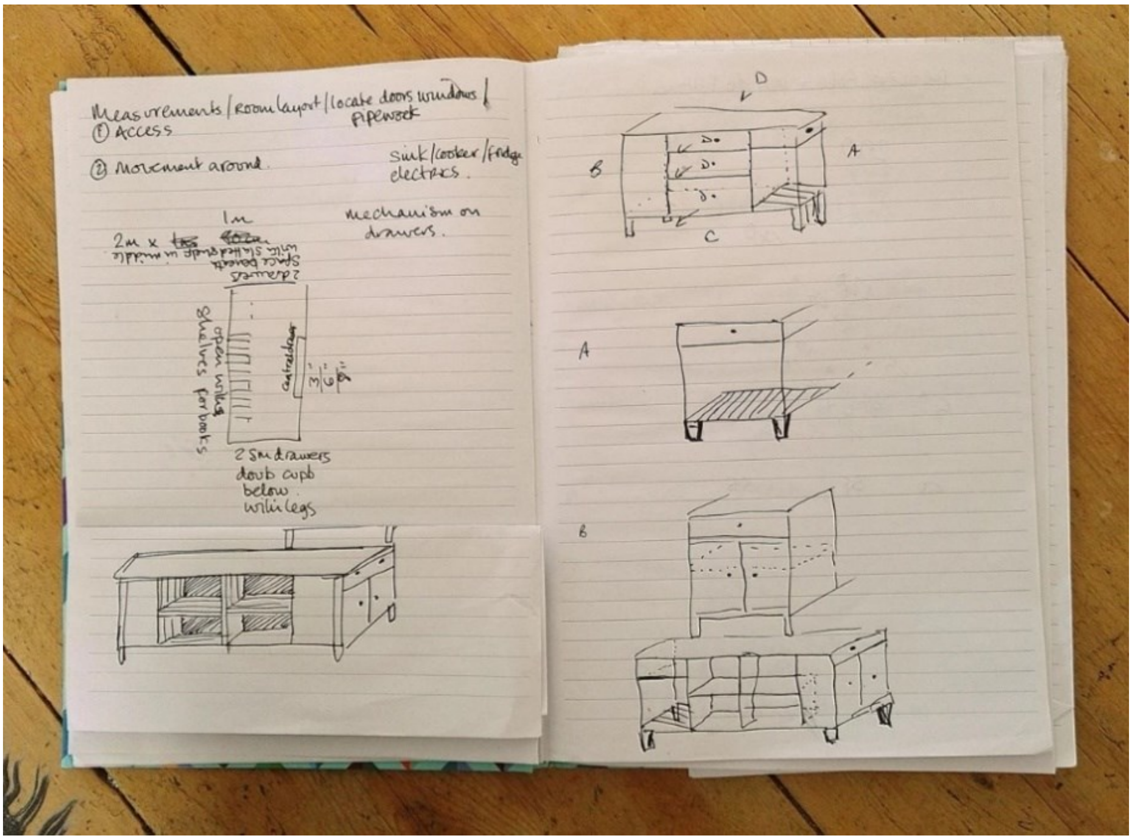

Figure 2.4. Example of furniture doodle (Harvey, 2017).

2.1.2 VISUAL MATERIAL FROM SECONDARY SOURCES: MOOD BOARDS, MATERIAL BOARDS, PHOTOS.

Boards like the one below in Figure 2.5 commonly use a collage of images to showcase and evoke the interior style and „mood" of a space. The images are usually of materials, color palettes, furniture and other decorative details that communicate an aesthetic focus, which can sometimes include promotion of a certain lifestyle. Sometimes several boards are created to help elicit and determine the desired outcome. This method is a fast track to support and even replace verbal communication, and to develop a baseline aesthetic structure in the preliminary stage of design. The viewer is able to see the images and interact with the 2D screen or paper the image is presented on, which works well as the purpose of this method remains in the aesthetic measure.

Figure 2.5. Example of kitchen design inspiration mood board (*Moodboard Fun!*, 2019).

2.1.3 TWO-DIMENSIONAL VIEWS AND SECTION CUTS WITH MEASUREMENTS.

Two-dimensional technical drawings and elevations, like shown on Figure 2.6, are commonly done in orthographic view that present objects from top, front, and side view. More complex objects require one or more section cuts to show hidden constructions and details. Technical drawings generally use symbols which are not obvious for people unfamiliar with the production industry, and usually need legends that explain various markings on the drawing. Sometimes an in-scale human silhouette is added to technical drawings to present scale, i.e., taking a 2D human symbol as a reference to a 2D drawing. Technical drawings are used in the building and construction stage of the design solution and therefore, measurements are essential.

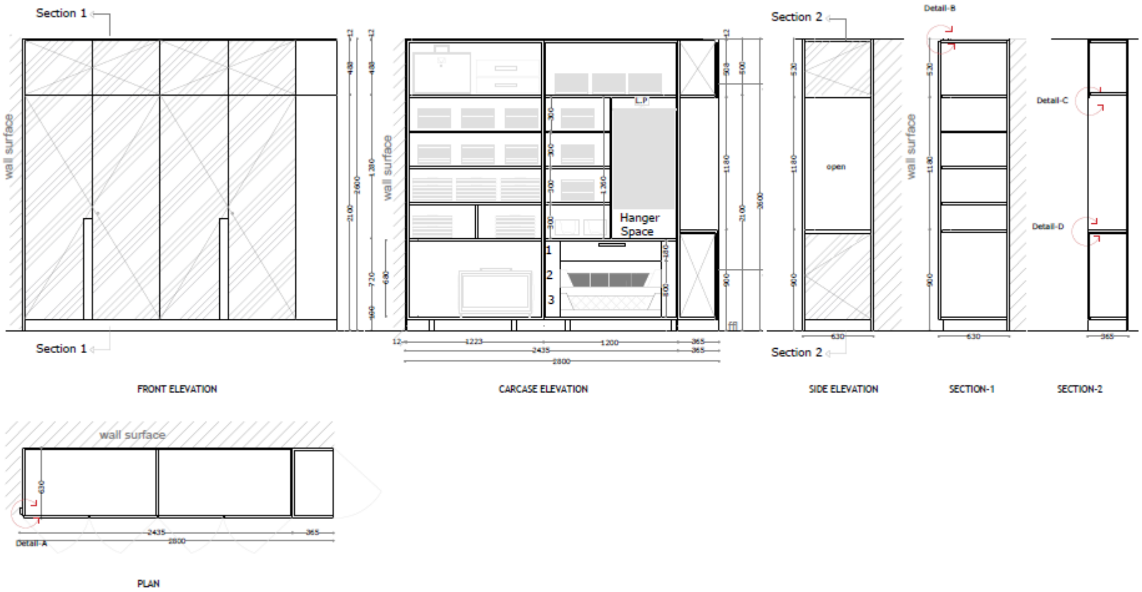

Figure 2.6. Example of technical drawing of a wardrobe (Halim, 2021).

2.1.4 SAMPLES OF MATERIALS, OBJECTS, FABRICS, AND COLORS.

Samples are commonly introduced as small pieces of materials to demonstrate their main features, which can be experienced in real life through human senses. Objects, such as cabinet handles or water faucets, are also presented as samples generally in shops and salons; however, the total selection is not always available as samples. Materials and objects experienced in real life offer a broader comprehension than just visual experience. In this method of presentation, as shown on Figure 2.7, the samples can be interacted with beyond digital barriers such as screens. Presentation of samples is practiced throughout the design process.

Figure 2.7. Example of material and fabric samples (Goddard, 2021).

2.1.5 LOW-FIDELITY ROTATABLE 3D MODELS AND PHOTOREALISTIC RENDERINGS.

These methods of presentation are usually a perspective view images of spaces and objects. 3D rendering commonly requires a three-dimensional model to be built in modelling software, after which a rendered image can be created. Depending on the level of detail, they can be either low-fidelity rotatable models (Figure 2.8) or photorealistic perspective images completed with details like textures, light, shadows, finishes, and decorations (Figure 2.9). Utilizing low-fidelity models may be used more in the developmental phase of the design, whereas photorealistic renderings are often used to showcase a detailed design. However, interior and furniture design service providers can use them in different phases. Osborne (2021) thinks that the introduction of 3D design software in interior design has been a game-changer for modern interior designers in recent years. According to him the days of 2D images and sketches are gone when they were the norm for showcasing products in the interior design industry. He believes the emergence of 3D modelling has rendered these methods obsolete, and they no longer hold relevance in today's highly competitive market. To effectively convey concepts and visions in a visually appealing manner that clients can understand and value, 3D rendering is essential.

Even though 3D rendering might be replacing outdated methods of conveying concepts and visions, the only way to experience a rendered image remains two-dimensional – visually via flat screen or printed on paper, where both act as 2D barriers. Even though a rendered image is a still-life and provides no other interaction other than viewing, photorealistic images paint a clear picture for the human imagination of how the space will look like.

Figure 2.8. Example of low fidelity 3D model (Yap, 2016).


Figure 2.9. Example of photorealistic rendering in interior design (Nicola, 2023).

2.1.6 AUGMENTED REALITY

This is a cutting-edge technology used in architecture or interior design applications, where AR imposes visual elements onto an existing physical scene. This emerging technology is accessed through a mobile device, such as a smartphone or tablet. By utilizing an AR-enabled app, users can enter into a camera-like mode, which allows them to observe virtual elements layered onto the backdrop of a real world (S. Elliott, 2022).

Swedish retailer IKEA launched a mobile application IKEA Place (Figure 2.10), that allows users to place finished products and furniture into their spaces via their smart devices through which the products stay true to size. (*Say Hej to IKEA Place*, n.d.).

With augmented reality applications the possibilities of viewing interiors and furniture are expanded through providing an opportunity to move around objects as the picture on the screen shifts along according to the user's movements. Even though AR technology can be considered cutting-edge, the digital moving 3D image nevertheless relies on a flat screen device. Apps like IKEA Place are available to the demand side of furniture ordering which gives an opportunity for the general public to try out solutions independently without the help of a designer. They also allow users to navigate between objects that are of high fidelity, which means the perceived object is visually realistic. In addition to independence and photorealistic visual, AR application helps avoid errors in measurements by allowing furniture to be placed in a space true to size (Shavel, 2022).

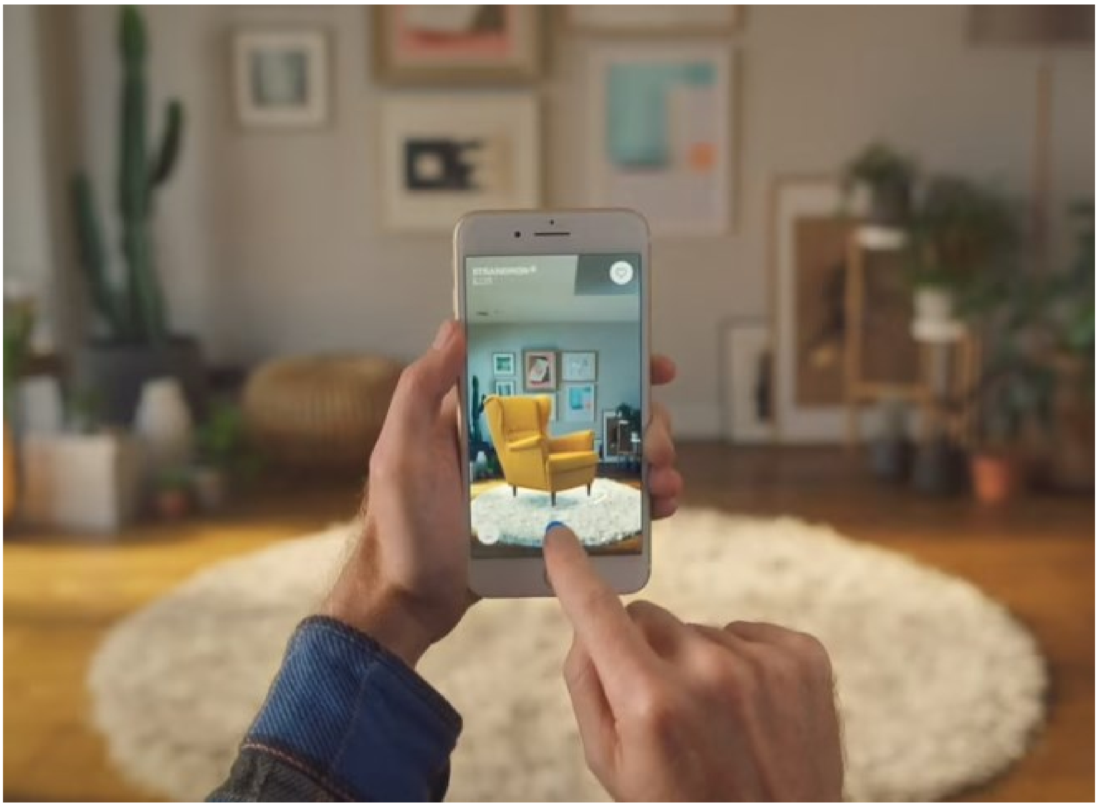
Figure 2.10. IKEA Place app for AR product placement (*Say Hej to IKEA Place*, n.d.).

2.1.7 VIRTUAL REALITY

S. Elliott (2022) describes VR as an immersive experience where the entire environment is digitally created. Virtual reality is accessed by a headset that transfers the user into a digital three-dimensional scene, where they can look around in a space as if they were standing there. It is an emerging and exciting tool for designers where the immersion and visual representation are unlike any other design presentation method by having a reference point that helps with visualization representation. VR is employed by designers to give a lifelike presentation of the floor plans and 3D renderings as some people find the interpretation of 2D drawings difficult (S. Elliott, 2022).

Jämsén (2023) explained boat designers in their agency Aivan use VR headsets as a tool to design when they check the dimensional quality of their designs before introducing it to their customers. After a design has been prepared, the customer can then come along to the VR journey to meet the aesthetic, structural and functional qualities of their boat.

According to David Alhadeff (cited in Baka, 2018) the use of hypothetical reality seems better than having to sign off on an idea based on a drawing by getting a peak into the future space. Additionally, it is proposed that virtual reality's dimensionality and depth appear to be superior for exploring built environments. Whereas augmented reality's immediate accessibility and ease of use may make it the preferred choice in design until VR technology becomes more seamless. Virtual reality is used in interior architecture, where sample apartments are fully virtually accessible and allow users to change the design such as parquet, tile, and even wallpaper (Liven, n.d.).

For an immersive experience virtual reality is visually as realistic as possible (Figure 2.11) to convey the same features as a rendered image, which means textures, light, shadows, finishes, and decorations are refined.

Figure 2.11. Example of VR view of kitchen furniture (Virtual Reality Apps, 2021).

2.1.8 AESTHETIC PRIORITY AND LACK OF INTERACTION

Learning about current and emerging methods used to convey interior spaces and furniture has revealed that these common methods of spatial presentation primarily focus on aesthetic values of furniture and prioritize aesthetic tools to design furniture. Whereas the functional and dimensional apprehension of bespoke furniture requires interactions to be explained verbally. Verbal communication between designers and stakeholders is practiced in face-to-face meetings, telephone conversations or written communication via email or instant messaging. Verbally explaining the furniture in visual presentations allows customers to imagine use case scenarios and activities, that might otherwise go unimagined.

Perolini (2011, p 167) concluded a message from Lefebvre's book "The production of space" (1991) with the following: "*Space is not an empty volume waiting to be filled but rather it is a product that can't be separated from human activity, likewise it is affected and affecting that activity.*"

Ensuring the connecting human activities into the spatial design process becomes particularly challenging when design presentations rely solely on static 2D visuals and verbal descriptions to convey furniture aspects. Such limited means may risk overlooking the nuanced connections between human behavior and spatial arrangements. The insufficiency of immoveable visuals often falls short in explaining the functional, actionable, and dimensional aspects of furniture. However, simply observing an image of furniture may not sufficiently capture the diverse ways people engage with it. Some common modes of interaction with furniture include the following:

- **Sitting:** Furniture such as chairs, sofas, and stools are designed for people to sit on. People may sit for either short or extended periods of time while working, relaxing, or engaging in other activities. Whilst sitting doesn't seem a particularly interactive activity, the action of sitting down and getting up from a seat are important to consider when designing seating. However, looking at an image of a seating can, but might not, provide an accurate experience of what it will be used for, and how.

- **Sleeping:** Furniture such as beds, futons, and hammocks are designed for people to sleep on. People may use these pieces of furniture for rest and relaxation, or to meet their physical needs for sleep, but there are many other activities for which a bed is a part of that need consideration. Whilst sleeping itself can be considered as a comparatively passive function, the actions around sleeping, e.g., getting into bed, reading, putting the book down or shutting off the lights might have an impact on the design of furniture. Again, choosing a bed from a website and trying to imagine its' size or softness might be inaccurate.
- **Eating:** Furniture such as tables, chairs, and benches are designed for people to sit at while eating. People may use these pieces of furniture to enjoy meals, but also socialize, or work on projects. Along with the activity of eating, kitchens are generally used for food preparation, which is a major active part around eating and encloses countless small activities and interactions which are important to keep in mind in the design process. The activities and interactions require to be experienced, in other ways than merely visually, to ensure satisfaction.
- **Storing:** Furniture such as cabinets, drawers, and shelves are designed for people to store items and may use these pieces of furniture to organize and store their possessions, like clothing, books, or kitchen supplies. Thereby, activities such as putting things to storage, finding items in storage, and taking items out of storage are crucial part of the seemingly passive idea of storing.
- **Displaying:** Furniture such as shelves, cabinets, and tables can be used to display decorative things or other items of interest and everyday use. People may use these pieces of furniture to showcase their personal style and interests, but displaying as such is not frozen in time as it is on an image, but is a process of removing, adding, or switching items of display.

Visually presented designs are immoveable, frozen in time, and without possibilities for interaction, which leaves a substantial gap in what the furniture was created for – using. For the customer it can be difficult to imagine performing activities with their future furniture based on still-life images that are presented on 2D interfaces. The interfaces for design presentations do not provide the opportunity for the customer to immerse themselves in their future space, which disassociates the customer from their furniture.

In some ways, cross realities such as AR and VR, offer an opportunity to evaluate spaces and furniture regarding its dimensional and interactional qualities. In contrast to common practices using still images, these technologies offer a moving picture considering real scale, which can generally help with understanding interior spaces.

The lack of focus on interactional, functional, and dimensional qualities in design presentations can be responsible for difficulties in understanding and also conveying spaces to customers. Spatial design presentations can be difficult to understand because interior space and furniture that are yet non-existent in the real world cannot be fully evaluated with only visual information but require actionable options for evaluation. Moreover, incomplete evaluation may disregard requirements and needs for interior spaces; thus, it is crucial to provide opportunities for various ways of experiencing and evaluating custom-made furniture. To be aware of difficulties that may arise with understanding spaces, and to evaluate if AR and VR could be helpful with preventing these difficulties, further research is necessary.

2.2 UNDERSTANDING SPATIAL DESIGN THROUGH VISION AND COGNITION

The way we experience interior space relates to how we understand it, and the understanding of interior space depends on how we experience it. So how to experience space that does not yet exist and is only to be designed and created in the future? Perhaps, the best option would be to build the exact replica of the planned space and furniture – a high-fidelity prototype – then interact with it, view it, use it, evaluate it, followed by rebuilding the space with evaluation information received from the initial experience with the prototype. This way, a proper evaluation of *aesthetics, structure and materials*, and *functions* can be done. Additionally, the customer is allowed to engage with the furniture intuitively and use their cognitive skills, by creating their own use case scenarios and tests to evaluate the furniture. It relieves them from barriers of complex information that attempt to convey functional and dimensional aspects of furniture. A high-fidelity prototype, however, is an unreasonable option due to a waste of effort, money, resources, and time, and thus calls for alternative ways to be able to interact with furniture, all with minimal waste.

Pile (1995b, p 42) writes that vision is the primary sense for comprehending design, emphasizing that "*no verbal description can ever equal the knowledge of reality that comes from actually seeing*." The human mind constructs 3D objects based on visual information, creating a cognitive model stored in memory. While mental models can be formed through images, truly grasping space and its qualities requires physical exploration, involving both motion and time. Norman (1993) distinguishes cognitive processes as *experiential* and *reflective*, with experiential cognition being intuitive, and reflective cognition involving deliberate analysis. In the context of interior design, experiential cognition applies to simple activities like sitting on a sofa, easily imagined through images. Reflective cognition, however, requires deeper engagement, involving considerations such as fabric type, dimensions, and suitability for specific needs, highlighting its importance in decision-making for proposed designs.

Customers choosing furniture need to understand their requirements and how furniture features meet those needs. However, envisioning the full experience of sitting on a sofa can be challenging, even with detailed verbal information and realistic images. Verbal descriptions, such as 'the seat height is 50cm' and 'covered with velvet fabric,' may not be easily relatable for customers, requiring tools like a measuring tape to comprehend dimensions. Interacting with materials, like velvet fabric, is essential for understanding their features. People vary in their ability to imagine spaces, and presenting new interior designs serves as an educational medium, requiring customers to familiarize themselves with technical drawings, material terminology, and align designs with their preferences and needs.

The success of understanding new information hinges on cognitive load theory, which posits two key concepts: the first being a limitation on how much new information the human brain can handle simultaneously, and the second alleging that there are no known boundaries to the simultaneous processing of stored information (Sweller, 2011). Zakrajsek (2019) says Sweller’s (2011) theory of cognitive load is fundamental for understanding new information as it defines the learning limitations for the human mind. It helps us understand that some people resonate with one type of information, but the same information can be difficult to understand for others, such as envisioning real spaces through perspective pictures or understanding expert words in design. Zakrajsek (2019) talks about two kinds of thinking loads. One is distracting stuff that stops us from learning (extraneous load). In design, it means distractions in spatial design presentations that keep us from focusing on what really matters. The other is useful thinking (germane load) with two parts: doing things without much thinking (automaticity) and using past experiences to understand new things (schemas). For example, someone who drinks lots of coffee doesn't need to think about where the cups are in their kitchen because automatically know it. As well as schemas help us make coffee in someone else’s kitchen. Zakrajsek (2019) points out a crucial takeaway, that every person's brain is different, so what makes sense to one individual might confuse another.

These types of cognitive differences disclose the complexities of conveying information to different people and affect design practices. It also highlights the importance of accurate and relatable communication when it comes to expert knowledge. The information that customers receive about the features of their furniture and interiors must resonate with their cognitive understanding in order to uncover their expectations and needs, and to make the best decisions.

2.2.1 DAUNTING DECISION-MAKING

Customers are required to make costly decisions based on complex, overwhelming and incomplete information. When faced with an abundance of unfamiliar options, deciding can be a daunting task. According to rational theories of decision-making (von Neumann & Morgenstern, 1944) the process of making a choice involves carefully weighing the costs and benefits of each available option, which requires an exhaustive analysis of information and trade-offs between features. However, such decision-making strategies can be costly and tiring in terms of resources. Especially because they necessitate a comparison of different options, where mental overload can lead to analysis paralysis, and wrong decisions to buyer's remorse. Buyer's remorse is described in Cambridge Dictionary (n.d.) as *"a feeling of regret (= a wish that you had not done something) after making a choice or decision"*. Charlton (2022) and Raypole (2020) explain analysis paralysis, also known as purchase paralysis, where one is unable to come to a decision due to over-analysis of options, heightened cognitive load and uncertainty.
On the other hand, cognitive psychology research (Gigerenzer et al., 1999) highlights that people often rely on simple examination in decision-making, driven by the human mind's preference for quick, "good enough" decisions using fast heuristics. This approach involves overlooking most available information, focusing on a few key cues, and varies among individuals. This tendency to base

decisions on easily understandable information is to avoid cognitive overload (Gigerenzer et al., 1999).

Creating an environment that allows customers to engage their intuitive processes becomes crucial for evaluating interiors and making straightforward decisions prior to furniture construction. *Bounded rationality*, a human decision-making process (Why Are We Satisfied by “Good Enough?”, 2023), aligns with this approach, emphasizing satisfying rather than optimizing, and seeking a decision that is satisfactory rather than the best possible. Due to cognitive and temporal limitations, individuals employing bounded rationality often avoid exhaustive searches for information, relying on heuristics as mental shortcuts. Although these shortcuts facilitate quick judgments, they can limit logical reasoning, sometimes leading to suboptimal choices. Understanding bounded rationality's constraints doesn't eliminate them, and attempting to acquire exhaustive information is impractical due to time constraints and cognitive limitations (Why Are We Satisfied by “Good Enough?” 2023).

It can be concluded that customers need simple and applicable information to understand spaces and make decisions, but it is problematic. Current practices in interior and furniture design include information that not only lack interactional and dimensional components but consist redundant information that can cause cognitive overload and inhibit decision-making. Background research into furniture design practices alongside cognitive psychology and vision supports the need for new methods that encourage customers to be active participants in the design of their furniture; although, the practical manifestation calls for further research. The specific problems with spatial presentations that cause difficulties with understanding can be disclosed with additional studies. Theoretically AR and VR technologies along with their interactive features support active engagement with spaces. However, detailed information to which extent they assist or hinder the understanding of non-existent spaces still needs uncovering.

2.3 STAKEHOLDER REQUIREMENTS ENGINEERING AND ELICITATION

While design presentations are an important part of a design proposal to convey spatial solutions, the solution is not a good one if it doesn't align with requirements. As mentioned previously, spatial requirements can be categorized relying on Pile's (1995b) aspects of quality furniture: aesthetic, structural and material, and functional. To ensure appropriate solution and successful spatial presentation, accurate input, and feedback from the customer - *aka* stakeholder - are crucial in guiding the design process. But how do customers know what they want? How can they know which aesthetic, material and structural, and functional needs they have? The needs that customers know they have (conscious requirements) should be communicated, structured, and documented. The needs that customers do not know they have (unconscious requirements) should be prompted and elicited before they can turn into conscious needs.

2.3.1 PROBLEM-FORMULATION THROUGH SYSTEMS REQUIREMENT ENGINEERING.

Some needs that customers consciously have may be disguised as requirements, but are actually solutions that they're asking for. To accurately identify requirements, it is essential to work in the problem domain. Effective requirement communication can be hindered by asking the wrong questions, making it challenging to design a solution for an unidentified problem.

Dick et al. (2017b) caution against the temptation to pose solution-oriented questions when eliciting requirements from stakeholders. Rather than asking, *"What do you want the system to do?"*—where the system in this case refers to furniture or interior solutions—they suggest posing a fundamental question: *"What is the purpose of the system you want?"* to encourage thinking what they desire to accomplish with the furniture. This is crucial because some customers have no idea about what they want their interior and furniture system to do. Other customers might be able to answer the question based on previous experience with furniture, but they are inclined to come up with a solution-based answer, because of how the question is posed.

To ensure the design solution is built appropriately, *a requirement engineering process* used in software systems can be utilized. This process can assist in discovering and analyzing spatial requirements of someone in the process of ordering furniture or interior solutions. Dick et al. (2017a) explain that requirements engineering is an essential component of the systems engineering process. They define the specific functionalities that the system must possess in order to meet those identified needs. Nuseibeh & Easterbrook (2011) explain that the success of a software system is primarily measured by its ability to fulfill the intended purpose for which it was developed, and requirements engineering for software systems involves the central process of uncovering this purpose. The concept of fulfilling the intended purpose for which a system was created applies to interior and furniture design solutions well. Interior and furniture design can be seen as systems that rely on specific requirements in order to serve their purpose effectively. Therefore, it is appropriate to consider them as systems in their own right. By employing requirements engineering principles, it becomes possible to engineer interior and furniture systems that meet the desired goals.

Penzenstadler (2018a) describes the process of requirements engineering in software development as follows:

1. *Requirements elicitation.* Asking stakeholders about their needs, wishes, and constraints.
2. *Requirements analysis*. The designer analyzes whether requirements fit together or if there are any contradictions. Open questions and conflicts will be solved by reverting back to stakeholders.
3. *Requirements documentation.* After receiving requirements, documentation refers to writing down all requirements and returning back

to stakeholders to confirm if the designer has understood everything correctly.

4. *Requirements verification & validation.* Verification refers to confirming if documentation is correct, or “Am I building the system correctly?”. Validation refers to confirming with the stakeholder if this is what they need, or “Am I building the right system?”

This process of requirements engineering ensures the customer’s conscious needs are exposed, communicated, and confirmed, also in spatial design. Nonetheless, it is not without its challenges. Penzenstadler (2018b) discloses challenges (seen on Table 2.2 below) that may surface in the process of requirements engineering within software engineering; however, the challenges fit customers’ spatial needs context when it comes to structuring their needs. The examples below illustrate the importance of accurate communication, structuring, and documenting of customer requirements.

Problems in requirements engineering process (Penzenstadler, 2018b)	Problem example in interior and furniture design context
Incomplete / hidden requirements. It means designers didn’t remember to ask about everything, maybe customers didn’t remember to voice every need. Hidden requirements mean there might be different agendas and needs for different stakeholders, and other stakeholder’s needs can get overlooked depending on who presents them.	A parent ordering wardrobe furniture for their child might forget to say their child practices ice hockey, which means the designer will overlook the need for storage space in the wardrobe for the ice hockey equipment.
Inconsistent requirements. This occurs when one requirement contradicts the other.	A couple living together, where one person is significantly taller than the other, need the bathroom sink to be on a different height for comfortable use.
Terminology. The same terms might mean different things for different people.	When a customer ordering kitchen furniture asks for a “stone worktop”, they might mean “a hard impenetrable surface”, while the designer translates this into “worktop cut from natural stone, and not quartz”.

Unclear responsibilities. Unclear who is allowed to state requirements and which stakeholders and requirements are most important.	Ordering furniture and interior solutions for a home office that is used by someone other than the one presenting the needs and wishes might be problematic as the user's needs are not heard.
Communication problems. Problems in structure, chain of responsibility, people writing short emails without explaining enough, people communicating in different cultures, and different habits	Someone using vague words to describe an aesthetic requirement like "clean and bright" could be misunderstood and they might receive entirely white-toned interior solution. But in their mind, their request meant lots of storage and a clutter-free solution.
Moving targets. Stakeholders change their opinion about what they want. The problems are not moving forward with the project and running overtime. They need to make sure to stick to baseline requirements and that they sign off on them before going over budget.	Deciding to change the board material for front panels in the kitchen could mean the solution cannot be produced anymore due to technical inconsistencies. This change results in a situation where the designer needs to come up with a new, technically feasible solution.
Technically unfeasible requirements. Sometimes it is impossible to deliver something and in these cases it's important to have at least one domain expert.	A client choosing a large dinner table and requests to have its' legs made from 1cm x 1cm square metal rod, is technically unfeasible, and this information needs to be known to the stakeholder and changed before any production can begin.
*Stakeholders***.** Stakeholders are not experts, so stakeholders don't know how to separate between what they knew as a previous solution and what is it that they actually require.	Someone ordering a custom-made sofa might state that they need a firmer sofa because their previous sofa was too soft and thus uncomfortable to rise from. However, what they might actually need is not a firmer sofa, but simply a higher sofa.
Underspecified requirements. It is unknown which one of possible interpretations is the one that they needed.	If a requirement is "I need to have my dishwasher door and drawer for plates open at the same time" without any other explanation, it can be fulfilled, but wrong. The dishwasher and plates drawer may end up on opposite ends of the kitchen. So, the requirement is met, but not the purpose, which was to load plates straight from the dishwasher to the drawer. The requirement should have been specified as "I need to be able to load my plates straight from the dishwasher to the drawer."
Unclear, unmeasurable & non-functional requirements. Requirements need to be measurable.	A requirement for "I want a dim light" can be misinterpreted, which means that an agreement on strength of light in lumens might be necessary.

Table 2.2. Connection in challenges systems requirements and interior design requirements.

A quote from Steve Jobs illustrates the issues in requirements engineering and elicitation well as the method to dig for requirements means working in a problem space, where focus is on an ability to perform an action, and not the solution space, where the focus on the solution might be biased.

"Some people say give the customers what they want, but that's not my approach. Our job is to figure out what they're going to want before they do. I think Henry Ford once said, "If I'd ask customers what they wanted, they would've told me a faster horse." People don't know what they want until you show it to them. That's why I never rely on market research. Our task is to read things that are not yet on the page." (Steve Jobs, cited by Aten, 2021)

The quote might be misunderstood as discouraging user research, but it is important to listen to user input and do user research. The thought within the quote, however, illustrates difficulties users face to identify their needs as problems, and articulate them. Incorporating clear methods for requirements elicitation and structuring is important to build a strong foundation to the design solution, which is based on problems.

2.3.2 ELICITING UNCONSCIOUS REQUIREMENTS THROUGH CO-EVOLUTION.

What to do with the needs that customers don't know they have? What happens when requirements are not only hidden from the designer, but also from stakeholders themselves? If the customer doesn't know what they need, the needs cannot be articulated. It is a paradox where in order to identify requirements, a solution must be created, but to create a solution, requirements must be identified. The paradox can be discussed within a co-evolution concept. Crilly's, (2021) study on co-evolution, building on Darke's (1979) *primary generator* concept, points to the intertwined nature of design concepts and requirements. Darke's idea suggests developing design concepts simultaneously with defining requirements. Presenting design concepts and enabling interaction with the solution reveals unconscious requirements, which in turn influences further design development. Co-evolution, distinct from the requirements engineering process, focuses on prompting and eliciting problems and surfacing additional requirements.

Use scenarios can be employed to make sure requirements surface and are brought from unconsciousness to consciousness. It means different situations or *scenarios* in which the customer interacts with or *uses* their furniture. These situations can involve actions that the customer takes to complete a task, and considering other stakeholders in the same space. This allows the customer to think about their capabilities and focus on what it is they want to be able to achieve with custom-made furniture. Dick et al. (2017a) propose that *use scenarios* are a means of establishing a framework in which precise requirements can be generated. They represent capabilities without saying how to provide them and for this Dick et al. (2017a, p 100) suggest a model with the following procedure:

- *"Start with the end goal.*
- *Derive the necessary capabilities to get there.*
- *Break steps into smaller steps*
- *Keep the steps hierarchical.*
- *Review informally at each stage.*
- *Be wary of defining solutions."*

Based on the *use scenario* example depicted in "Requirements Engineering" book by Dick et al. (2017a) another *use scenario* example related to bedroom furniture can be created (Figure 2.12).

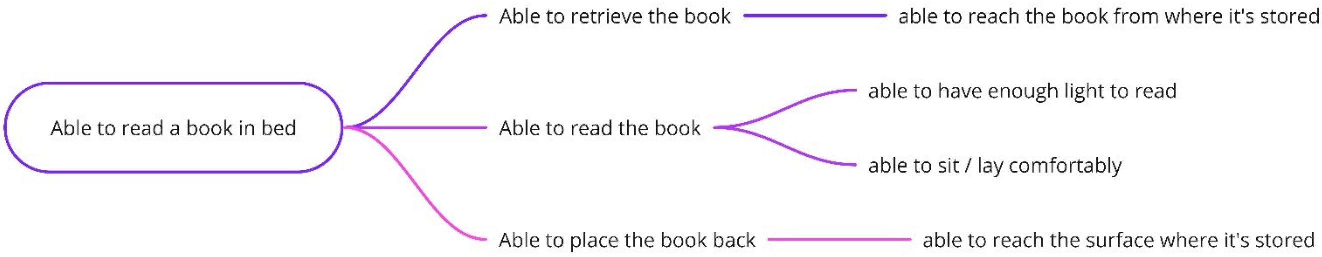

Figure 2.12. Example of *use scenario* in bedroom furniture context.

This method provides an easily understandable framework of capabilities for both the customer and a designer and places the requirements into context (Dick et al., 2017b).

Visual 2D representations of spaces and furniture can make it difficult to imagine step-by-step actions as they lack the opportunity to place oneself in relation to the furniture. However, employing a *primary generator* along with *use scenarios* provides a rehearsal type situation where the customer is given the opportunity to think about actions that they want to achieve in order to surface needs they didn't know they had. To achieve this, customers must fully grasp the design, which emphasizes the importance of integrating co-evolution principles. Allowing interaction and evaluation of the space before producing the furniture is key to avoiding dissatisfaction and loss of resources. Further research is essential to uncover how designers structure and elicit their customers' known and unknown needs, especially for those relying solely on visual means.

2.4 RESEARCH SUMMARY

In the realm of interior and custom-made furniture design, effective presentation is crucial for evaluating aesthetics, structure, materials, and functionality. The conventional approach involves conveying design concepts and furniture solutions through 2D and non-interactable visual images, but this practice often falls short in providing interactive experiences and functional understanding. The absence of interactive elements not only leaves unconscious questions unanswered but also contributes to potential misunderstandings in design presentations. The challenge lies in the inadequacy of these presentations, filled with complex information, and limited to visual means, hindering the necessary comprehension to envision rooms and furniture as dynamic, functional spaces.

Background research provides circumstantial insights, yet the intricacies of understanding furniture and interior design complications become apparent through direct research. Deeper exploration unveils the difficulties in grasping and presenting spatial designs, while also shedding light on potential gaps in functional, material, and structural opportunities, that warrant exploration in future services. While AR (Augmented Reality) and VR (Virtual Reality) technologies hold promise in improving understanding the design presentations through dynamic features and interactive reactions, further studies are imperative to unlock their full potential.

To grasp non-existent spaces fully, a thorough evaluation of functional, aesthetic, material, and structural features is essential. This necessitates a deeper and reflective engagement achieved by physically entering, moving within, and interacting with space. The current reliance on visual information alone poses challenges, as customers seek straightforward and applicable data for informed decision-making. Research gaps emerge in understanding how customers interpret complex spatial solutions communicated solely through incomplete yet abundant visual means, potentially leading to cognitive overload and decision-making hurdles.

Drawing from the requirements engineering process in software engineering unveils communication challenges between customers and designers. Eliciting and structuring requirements become paramount to guide the design process, emphasizing the framing of requirements as problems and focusing on capability goals to avoid solution bias. The extent to which designers knowingly or intuitively incorporate this concept to support their design remains unclear, which emphasizes the importance of effective communication and understanding unconscious requirements.

While augmented reality and virtual reality technologies hold the potential to evaluate spatial and dimensional qualities, their commercial utilization is not widespread. These emerging 3D technologies provide dynamic, life-like representations on a real scale, while offering a departure from common practices that rely on images. Although these technologies offer seemingly immersive experiences, the specific ways in which they can support spatial understanding remain uncertain, presenting numerous opportunities yet to be uncovered in interior and furniture design.

3 METHODS

The posed research questions focus on understanding what makes the presentation and understanding of non-existent spaces problematic. Additional research reveals the design practices currently used, and aids with identifying areas of difficulties. For this, insightful discussions with people that have experience with the topic of study will be held. The primary focus for research outcome lies in examining the methods designers employ to present their designs, the impact on how the customers can understand the designs, and how requirements communication is considered. The perspectives of both, designers and customers, are examined, offering a wide inspection of the design process from multiple angles. The participants' narratives allow exploration of the complexities ingrained in each project and provide valuable context to understand the nuances of the design process. Deeper engagement in personal and real-life experiences will give information that background research does not offer.

Additionally, exploring the potential role of AR and VR technologies as design presentation methods becomes essential. These technologies can enhance spatial understanding and facilitate requirements elicitation; and to understand the complexities and opportunities AR and VR technologies can provide, test runs will be conducted.

3.1 SEMI-STRUCTURED INTERVIEWS

To retrieve data for RQ1 *"Which difficulties arise with understanding and presenting spatial and furniture design solutions?"* semi-structured interviews are conducted with seven interior and furniture designers; and three customers that have experience with ordering custom-made furniture.

I. *Interviews with designers.* Designers were prompted to introduce their practices of creating and presenting their designs to customers, and asked to show specific documents of their work methods. This was to understand which presentation methods provide which type of information, and if interactive aspects, not merely aesthetics, are considered. This question relies on related research where the aesthetic priority was discussed. Designers are asked to think about and discuss where their difficulties within the design process lie through guiding questions such as when and why they feel discouraged, or in which moments they need to repeat themselves and hold their customer's hand. Designers were asked about experiences of how their customers have cognitively and visually understood the designs and if they could imagine the real-life spaces to uncover issues with comprehending functional, structural, and material aspects of furniture. Designers were asked to explain ways in which they receive and understand customers' needs and apply them to their designs. This question challenges the depth in which customer requirements are considered and aids to understand at which point they and their customers struggle. In addition to hearing their voice on problems in their working methods, opinions on using emerging technologies such as AR and VR were asked to get insights into how utilization of new practices are received.

II. *Interviews with customers.* Customers were prompted to share their specific experiences with ordering custom-made furniture. They were asked to introduce their experiences with understanding the solutions their designers presented and which difficulties they faced with comprehending those. This reveals which aspects of the designer's presentations might have been confusing and difficult to understand, especially in the context of analysis paralysis, bounded rationality, and mental overload. Customers were asked to share how they communicated their needs, if the solution fulfilled their needs, and if their needs ever changed after interacting with the furniture. These questions help gain insights into how requirements elicitation and structuring could be done to fulfill their needs. Additionally, a discussion about accepting AR and VR technologies was held to understand their interest and worries about using the new methods.

3.2 AR AND VR TECHNOLOGY TRIALS

To retrieve data for RQ2 *“Could additional use of virtual and/or augmented reality technology in design presentations help prevent these difficulties?”* trials with AR and VR technologies were conducted. The task was to simulate a spatial design process involving study participants acting as a customer, and myself in the designer position. It is important to mention that neither the participants nor I have any experience using AR or VR in spatial design. The assignment, within the realm of possibilities for a short-term study, includes creating a 3D model of a furnished kitchen-living room together with the customer and evaluating the use of AR and VR technologies in the process. An empty room was used as a test space (Figure 3.1; Figure 3.2) to simulate the realistic process of having a room with limitations to design in. Two participants were involved in the trial to aid with simulating designer-customer communication by providing unfamiliarity in the domain, reducing researcher’s bias, and being the person of observation. A customer’s persona is used to include their requirements for a realistic trial.

Customer’s space	Customer’s persona	Customer’s needs
• existing space • no furniture inside • small room • unrenovated condition	• male, height 180cm • lives alone • likes to cook and have friends over • pizza enthusiast • watches sports • fit, likes to exercise at home • generally messy • chronic back pain	• wants to be able to host friends • needs space to exercise at home • easily cleanable furniture • contemporary design • easy access for a robot vacuum

Table 3.1. Initial brief of persona, space and needs to start the spatial design process.

Based on information on Table 3.1, the work on the spatial design can begin, as the space, persona and requirements help set the interactive needs. To kickstart the design process, a first design solution, or a *primary generator*, is needed to allow for the design to co-evolve. To optimize resources such as time and costs, the utilization of artificial intelligence can provide the requisite knowledge for this task. A text-to-image image generator (*Imagine AI Art Generator*, n.d.), which is a creative technology capable of generating randomized aesthetic spatial designs (mood boards), was used. A prompt containing simplified aesthetic requirements was provided to simulate the custom-made furniture ordering process. The prompt text was worded as follows: *Interior design mood board containing materials and tones suitable for a contemporary kitchen and living room.* Four mood boards created by AI (Figure 3.3, Figure 3.4, Figure 3.5, Figure 3.6) were presented to the customer as a primary aesthetic generator from which a 3D model was constructed. The persona, requirements, the room, and mood boards gave a solid foundation to conduct the trials.

I. *Trial and evaluation of an AR mobile application.* IKEA Place application served as an AR platform for placing virtual furniture items into the test space, allowing us to evaluate the possibilities of preventing the issues disclosed in RQ1. It can be identified how understanding the aspects of interiors and furniture (functions, aesthetics, structure, and materials) can be supported or hindered. The task of placing and rotating furniture models to design the space is a novel approach to observe how the cognitive understanding of spatial design changes, compared to common and non-interactive visual means. Furthermore, while completing the task, potential challenges and benefits associated with incorporating AR into the custom-made furniture ordering process were observed. The opportunities to play out use case scenarios were discussed, based on the participants' uses of the space and furniture.

II. *Trial and evaluation of VR technology.* To evaluate the effectiveness of VR technology for the purpose of this study, a virtual model of our kitchen-living room was necessary. The virtual space was created using SketchUp 3D modelling program. Unity game engine was then employed to view the 3D immersive space through HTC Vive virtual reality head-mounted display (HMD). This approach allowed for the identification of factors influencing the cognitive understanding of interior and furniture aspects (functions, aesthetics, structure, and materials). The trial involved wearing a head mounted display and looking around in the virtual kitchen-living room. This method provided a unique perspective on how cognitive understanding of spatial design shifts, which is distinct from traditional non-interactive visual methods. Additionally, during the task, both challenges and benefits associated with integrating VR into the custom-made furniture ordering process were noted. The discussion also explored opportunities to simulate *use scenarios* based on participants' interactions with the space and furniture.

3.3 DATA SYNTHESIS AND ANALYSIS

To answer RQ1 *"Which difficulties arise with understanding and presenting spatial and furniture design solutions?"* the analysis was done in two parts. First, insights from the interviews were divided relying on spatial design process and communication (Figure 2.3). The processes were divided into the following groups, so the data could be analyzed comprehensively:

- *Obtaining and inputting requirements*. This group consists of data about how and if customer's requirements were collected and structured, and which methods were used to give and receive spatial requirements.
- *Presenting interior and/or furniture design solutions*. This includes data related to how design solutions were presented to customers, and which issues arose with this process. That data reveals insights into problems that designers face when it comes to using visual means to present designs.
- *Understanding spaces and design presentations*. The data related to this step provides insights on how customers understood the designs presented to them, and which issues they faced with processing and deciding on the choices. Furthermore, insights into understanding designs through visual and non-interactive means were sought after.
- *Feedback communication*. This group has data related to how feedback about unfinished designs and finished furniture was communicated. This includes

data on how requirements were fulfilled, and if any additional requirements surfaced after the fact.

Subsequent to separating the data into groups, insights to difficulties in each process surfaced by using the affinity diagram method, where insights of similar topics were grouped. The principles of requirements engineering were used to structure the insights in the problem domain. So, insights that arose needed to be analyzed in the context of reasons, capabilities, and consequences in order to fully understand the issues that customers and designers face.

To answer RQ2 *"Could additional use of virtual and/or augmented reality technology in design presentations help prevent these difficulties?"* these technologies were tested against the results from RQ1 using the initial design (primary generator) and analyzing how the design co-evolved. The findings from RQ1 offered an approach for assessing whether AR and VR can effectively prevent identified issues in RQ1. To explore this, delving into each problem area (revealed within affinity diagram) and posing guiding questions aided in evaluating the appropriateness of AR and VR. Information from cognitive load theory was considered when observing the participant and asking them to think out loud. Observation and thinking aloud provided the opportunity to discover insights, as neither the acting designer nor customer had any experience with using these technologies.

4 FINDINGS

This chapter embodies answers to the research questions posed in the introduction section. It reveals the synthesis of gathered data, and insights into the two questions driving this study, supported by evidence acquired through interviews and trials.

4.1 DIFFICULTIES WITH UNDERSTANDING AND PRESENTING FURNITURE DESIGN.

RQ1 encompasses several key topics and the answer to this question was analyzed by following these topics. The topics embed understanding interior space, presenting non-existent spaces and furniture, and communicating and fulfilling spatial requirements, drawn from Table 2.3.

However, subsequent analysis of study findings revealed that answering the question using these separate key topics is not fully reasonable. The findings cannot be divided by merely being grouped into requirements, presentation, understanding and feedback. As it turns out, many revealed issues do not strictly fit these divisions and often overlap. For example, designers find it problematic to explain their design solutions to the customer through email because of its narrow and limited communication possibilities. Similarly, customers find understanding the design solutions difficult for the same reason. Thus, the problems overlap because the reason is the same – a limiting communication channel. For this reason, the study findings are not only grouped based on the spatial design process flow diagram (Figure 2.3). Instead, the findings are further analyzed, regrouped, and explained based on the content of insights. The insights into issues that designers and customers face can be divided into eight fundamental subjects: 1) buried requirements, 2) mistargeted presentations, 3) lack of interactions, 4) ambiguous knowledge and terminology, 5) lack of independence, 6) waste of time, 7) limiting communication channels, and 8) missing feedback. Each problem is described relying on interviewees' voices. The voices of two interior architects, four furniture designers, one boat and yacht designer, and three customers with furniture ordering experience were heard. They disclosed issues with spatial design in various areas, some related to expected points discussed in background research, but also include unexpected findings that background research did not reveal.

EXPECTED FINDINGS

The focus of this research is discovering and explaining the problems that surround presenting and understanding spatial plans and custom-made furniture solutions before furniture is built. RQ1 was posed to find and understand issues customers and designers face for the purpose of improving interior and furniture design services. The following findings contain insights into these issues established from the stakeholders' experience.

4.1.1 BURIED REQUIREMENTS

Designers are inclined to ask solution-based questions as requirements, because they expect the customer to know their own needs.

"I ask if the clients could upgrade their furniture, then what would they do." – Designer 2

"I ask what the furniture could be like, about the preferred style of furniture, door profile. I ask about special wishes, such as coffee cabinet or high cargo cabinet." – Designer 3

"The place where I ordered from expected me to know what I wanted." – Customer 3

"I ask about the style, door profile, handles, photos [for inspiration], colors." – Designer 5

"I want initial input before meeting, and that the client has done at least some of their homework. They need to give as accurate input as possible, otherwise I will follow standards." – Designer 6

It is difficult to get clear requirements information about the customers.

"Some clients are very cryptic." - Designer 2

"I was frustrated when the customer didn't specify their needs, and problems emerged because of this." – Designer 6

"My questions are often answered with pictures, which are sometimes confusing." – Designer 1

"Sometimes I feel like I need to be a psychic." – Designer 5

"It's difficult if to not get input from the customer. They don't specify what they like about the furniture on the [inspiration] photo." – Designer 4

"Some clients' input is vague and controversial." – Designer 3

"I don't always observe the customers correctly because I don't go to their homes, and I don't know how they live or what possibilities they have." – Designer 1

"A customer has said that they are not satisfied, but they don't know what they want themselves." – Designer 3

"It doesn't seem humane, and instead a robot's job to think about every detail. How deep would you have to go with customer's [requirements] questionnaire to get all necessary information? You can't go this crazy." – Designer 3

"I sent the client on a field trip to look at beds and she came back with a favorite, which gave me a starting point." – Designer 2

"If I don't get enough input, it could happen that the customer doesn't like it at all. So, I fumble in the dark and hope I can hit the nail on the head. But if the input is sufficient, then I've got more confidence." – Designer 1

Requirements can change after seeing and interacting with the solution.

"After taping [the cabinet and TV dimensions to the wall and floor] I realized it'll be too small" – Customer 3

"We make 3D so that the customer would get a better picture of what they want." - Designer 1

"It happens often where the person thinks they know what they want, but once they see the solutions, they see the weak spots, which I already told them about." – Designer 1

Customers don't think about their requirements, and they are not aware of the necessity.

"People discover during the process that they need to think about their requirements. Most people don't bother to think about their requirements." – Designer 1

"During consultation I tell them [customers] where they should put their things, because people often don't think about it." – Designer 1

"As a patient you can't lay all possible elements to the doctor because the patient doesn't know whether they're symptoms." – Designer 3

"Oftentimes I choose the appliances because people don't have any requirements." – Designer 1

"There are more questions for the client than they might expect. There are many that don't have any input at all." – Designer 3

Designers and customers base and structure requirements on previous experience.

"Very often clients have been to multiple places and evaluated many places." – Designer 2

"It's compulsory for the customer to think it through if they want to continue with their old habits or if they're ready for something new." – Designer 1

"I visited another place with a similar layout and got the idea from there." – Customer 3

"The furniture of their friends and family is sought after." – Designer 5

"If one customer wants the same thing as the previous one, then I can use that experience as an example." – Designer 5

"Preferences are described from existing furniture." – Designer 5

"I ask them to observe themselves, how they live and why. I ask them to look what do they like about their current kitchen and what they don't like." - Designer 2

"I follow renovation influencers and there I got an idea for my tiles." – Customer 3

"I predict the questions they might get. Many customers want the same things, so a lot of the requirements are not new." – Designer 5

Requirements stay hidden, as customers don't voice every need, and designers might forget to ask about it.

"I don't have a document based on which I ask for questions [to understand requirements], but I ask whatever comes to mind during consultation. I ask based on other people's projects, such as how do they keep their jewelry and if they need a boudoir." – Designer 1

"They didn't ask how big my TV was. I was surprised that those places didn't ask so much." – Customer 3

4.1.2 MISTARGETED PRESENTATION

Design presentations are too difficult to understand for regular people.

"It is annoying for the customer to try to understand and make choices." – Designer 5

"The technical drawings need to be general enough for a regular person." – Designer 3

"Not knowing the client has a danger of designer offering too much information, that's noise for the client." – Designer 6

"Too much explaining is sometimes confusing for the client." – Designer 3

"Technical drawing is meant for the producer, not the client." – Designer 6

Customers are afraid to admit when they can't follow the design.

"The project moves on too fast for the customer to admit that they don't understand." – Designer 3

"People don't dare to say if they don't understand the technical drawing." – Designer 5

Too much information, and too many choices and details hinder the customers' decision-making.

"I'd rather explain thoroughly or send a photo or web link to clarify" – Designer 3

"During the design process, the customers ask a lot of additional information about materials, their features and differences." – Designer 6

"The more choices, the more doubts." – Designer 6

"The customer gets into error and shuts down about the abundance of options and they cannot choose." – Designer 6

"There's too much information."- Designer 5

"I make my own life difficult and lengthen the project if I give the customer too many options." – Designer 5

"One client told me to not offer them over two lightning options, because they would be confused. I've thought about reducing the options because it's easier for me and the client as well." - Designer 1

Balancing how much information the customer should receive is complicated.

"The less information the customer receives, the less unfavorable feedback there will be later." – Designer 6

"Customers have asked why I didn't explain x or y, so I started to explain more in depth." – Designer 5

"They didn't give me the floor plans, just showed it, and I took notes." – Customer 3

"The designer made the technical drawings based on my ideas, but I didn't see the drawings he made." – Customer 1

Current design presentation practices with visual means do not suffice.

"Just a picture is always from some angle, and you never see the other angle" – Customer 3

"I always emphasize that a tone cannot be decided based on the color on the screen." – Designer 1

"I think it was important to see the [sample] piece and I was lucky that I got quite big pieces." – Customer 3

"The customer has been shocked why their furniture is not as pretty as on the Pinterest photo." – Designer 3

"Actually, I couldn't imagine at all what it will be like." – Customer 1

"It's necessary to explain to the client at the space with a measuring tape, and to see and touch the materials understand what they'll get" – Designer 5

Every client needs different information to understand.

"Using all methods is a symbiosis for the client to understand, but every client requires different language." – Designer 6

"Some people need a 2D drawing to understand what's inside the cabinets" – Designer 3

"The customer can tell me later that I didn't explain in-depth enough, and that they thought it works differently." – Designer 6

4.1.3 LACK OF INTERACTIONS

Potential problems are hidden.

"In 3D models everything kind of works, but in the real world some things are visible which do not occur while making the 3D model." – Designer 3"

"If I see a solution that might become a problem later, I always warn the client in the email that it might be problematic." – Designer 6

"I warn the client that what they want might cause problems." – Designer 3

"Some dimensional problems or situations I think through and warn the person. Like if the coffee machine is too high or the shelf too deep, so that they might hit their head."- Designer 1

Aesthetic aspects are a priority and interactions secondary.

"Visual requirements are prevailing." – Designer 3

"I think that many only view the visual, but don't think about using the things." – Designer 6

"The client had seen a photo of a kitchen island on legs and wanted the whole kitchen like that." – Designer 3

"Those that come with their own Pinterest board, is about 50%." – Designer 1

"When clients see the design, it's important for them to understand it's not just pretty furniture, but it will become their reality." – Designer 2

Extra steps are necessary to imagine interactions, visual presentation does not suffice.

"It was good to use a [human] silhouette [while designing in 3D program] to find out whether the client can see into the drawer or not." – Designer 6

"The customer is responsible if they are willing to go to the shop or salon to see it for themselves" – Designer 1

"To help myself imagine I tried to tape my wall" – Customer 3

"I always tell my customer to try to simulate a situation in their flat" – Designer 1

"I went around with a measuring tape and tried to tape the cabinet sizes and even TV size"- Customer 3

Decision-making and planning are obstructed by lack of opportunities to test and imagine dimensions.

"I think it's a typical question if my bed will fit here." – Customer 2

"In one salon they drew the TV-stand, and they had a really small tv in the model and it looked nice, but my tv is bigger." – Customer 3

"It was quite difficult to imagine the living room furniture. It was difficult to think how wide it should be, and it was difficult to imagine and decide how far it should reach." - Customer 3

"I would have liked to test how it would really feel to have a bigger sink, if possible." – Customer 3

"I think many places were bigger [referring to inspiration photos on Pinterest] and to imagine how would it look like in my place was hard." - Customer 3

"I was hesitant to have the senkki [sideboard] too blocking for the living room." – Customer 3

"My mom is considering a lower worktop, but does she really need that low? Is standard really too high?" – Customer 3

4.1.4 AMBIGUOUS KNOWLEDGE AND TERMINOLOGY

The design solutions are complicated for customers to understand without expert help.

"There are logic mistakes [that customers make], such as if the drawer is 600mm from the outside, then it's also 600mm from the inside." – Designer 5

"I doubt more and more if clients understand technical drawings, overly technical solutions can be confusing to them." – Designer 6

"Typically, nobody will sit and explain the technical drawings." – Designer 3

"I have noticed that clients cannot read the drawings. They would understand the 2D drawings better if someone would sit next to them and explain." – Designer 3

"When it comes to electricity or finishing plans, then regular people don't really understand it. I have a strong sense of imagination, so I don't always need 3D models." - Designer 1

"The customer doesn't see the finishes from the technical drawing, even though they're there." - Designer 1

"The customers don't understand complicated technical solutions." – Designer 5

Customers can trust the designer without the need to get into every detail.

"I am not an expert in doing kitchens but if there's a professional, then I can trust them." – Customer 3

"Clients trust that if the designer tells them, it's good, then it is." – Designer 2

"You need to be able to sense if the customer cares about the technical details or not." – Designer 6

Explaining the design process and options is complicated.

"Explaining the solution should be structured better" – Designer 5

"You can't speak with the client about terms like "program" or "circulation"." – Designer 2

"I was explaining as to a child." – Designer 5

"The designer cannot be responsible for not offering the client all the options in the world" – Designer 3

Customers don't have the knowledge needed to ask domain-specific questions.

"Some things are so specific for experts that people don't even know to ask about them. For example, what's happening behind the doors or that there could be a drawer on top of the bins." – Designer 1

4.1.5 LACK OF INDEPENDENCE

Customers find it hard to make decisions on their own.

"If you can afford to use an interior designer, it's great to have someone hold your hand." Customer 3

"Interior designer helps so you don't have to make so many decisions yourself." – Customer 3

"With some customers you can see they're not able to make decisions." – Designer 1

"I got options but maybe for me it's difficult to decide so I asked my friends." – Customer 3

"In the kitchen it was hard to make practical decisions. If you don't have the interior architect, you have to do it yourself." – Customer 3

"Sometimes customers include their friends and family in their decisions, which sometimes works against their wishes." – Designer 1

"I have been to parties where there's marble and the owner is saying to be careful with the red wine, so I wanted it [their flat] to be a place to call home. So, then I messaged you and my friends to ask for advice. If I'm considering I need help deciding." – Customer 3

"The customer didn't know what they wanted, and this held back from decision-making. One of my clients moved into their home and lived without the kitchen for four months because they couldn't decide on their kitchen appliances." – Designer 1

Customers lack confidence with making decisions.

"My kitchen order took two months because I was considering everything." – Customer 3

"I generally have customer that need a lot of handholding, even when they've thought everything through." – Designer 6

"I considered worst possible situations with each solution and made my decision based on that. It was expensive so it was important to get it right." – Customer 3

Designers feel the need to set boundaries with their service.

"Holding the client's hand, I replied to him on the evenings and weekends, but my endurance ran out." – Designer 1

"As a designer giving too many options you could increase your responsibility." – Designer 6

"My client called me and wanted me to hold his hand while he ranted and thought about which fridge to choose."- Designer 1

"Knowledge comes from experience and to defend my behind, I find it necessary to warn the customer [of potential problems with furniture]." – Designer 6

Customers don't know their design options or possibilities.

"Often clients can't think where to put the bin in the kitchen." – Designer 2

"When a person moves into their new home, they don't think they can place things differently." – Designer 1

4.1.6 WASTE OF TIME

The process of designing, use of design tools, and decision-making needs to be faster to avoid frustration.

“I must say it was like a second job so that everything runs well.” - Customer 3

“I speak in human language [an expression meaning to speak in a simple language] to make the process go faster.” – Designer 5

“Clients signed off on projects just to get it over with.” – Designer 2

“I went to a place where the person couldn’t really use the 3D tool.” - Customer 3

“I am discouraged if making choices takes a long time.” – Designer 4

“They invited me back there to see the 3D model, they didn’t send it. I guess it was so that they could get your wishes right away.” – Customer 3

“They insisted we do the 3D model together and it took such a long time *shakes head*. He was drawing it on the computer while I was watching, but I was thinking it's a waste of my time. Some places were quite unprofessional, and I thought I could make better 3D models.” – Customer 3

“By the time the project is over, people are tired.” – Designer 1

Unclear communication is time-consuming.

“Some clients are very cryptic, which is very time-consuming.” – Designer 2

Indecisiveness and constant changes are exhausting and difficult.

“Changing the 3D model back and forth takes a long time.” – Designer 3

“I don’t edit the 3D model along with the client anymore, because they want too many changes.” – Designer 3

“If in the middle of the main project the client wants a purple kitchen instead of a black one, it messes up the whole project and we want to avoid that.” – Designer 1

“Changing confirmed choices is discouraging.” – Designer 4

“I get demotivated if I’m working on a project for too long and have to change multiple times.” – Designer 6

“As a client I wouldn’t want to waste others’ time with my lengthy choices.” - Designer 4

Even when designer offers solutions, the customer cannot decide on a suitable solution.

“I make my own life difficult and lengthen the project if I give the customer too many options.” – Designer 5

“The client changes their mind and doesn’t know what they want, because they consistently don’t like the proposed solutions.” – Designer 4

“I chose eight options [for a fridge] for him, which he was still unsatisfied with, and then I ended doing this because he hadn’t paid me for further pursuit.” – Designer 1

UNEXPECTED FINDINGS

The data uncovered insights into distinct root issues that differed from those addressed in the background research. While the anticipated findings were associated with requirements engineering, presenting spatial design, and comprehending and envisioning design solutions, the unexpected discoveries centered around the theme of communication. Communication emerged as a dimension stemming from both designers' and customers' experiences, an unforeseen yet noteworthy aspect that deserves attention.

4.1.7 LIMITING COMMUNICATION CHANNELS

Disorganized and loose information is difficult to structure for a clear overview.

“There are too many emails, and information is lost.” – Designer 4

Currently used channels don’t provide efficient communication.

“Long emails with explanations are not good.” – Designer 5

“If the customer has an image in their head, that they cannot convey, then there’s nothing to do.” – Designer 5

“Asking for feedback is great, but I don’t know how to ask for it over email.” - Designer 5

“It depends on the workload if I have the energy to go to the client’s place; I get tired from direct communication.” – Designer 6

“As a customer it would depend how feedback was asked. In the moment I wouldn’t be brave to say it, but over email definitely.” – Designer 3

4.1.8 MISSING FEEDBACK

Designers are afraid to ask for feedback for the fear of financial responsibility or compensation.

“What if the customer realizes that something is wrong, when I ask for it?” – Designer 5

“There’s a difference whether the client initiates giving feedback or if I ask. I’m afraid I’ll have to compensate for the mistakes.” – Designer 6

Admitting dissatisfaction and failures with the custom-made furniture outcome is embarrassing.

“It is easier to deal with negative feedback if I don’t feel embarrassment or responsibility” – Designer 3

“If the feedback is good, then it’s nice, but if not, then there’s embarrassment.” – Designer 6

Directly sharing and receiving negative feedback is avoided.

"I think there's a pretty large filter with what is shared and what is not." – Designer 1

"Someone else should ask for feedback, not the designer themselves." – Designer 4

"To get rejection for design solution is always hard, but at the end of the day feedback only hurts the ego." – Designer 2

There is no good time or place, or method to ask and share feedback.

"As a customer it would depend how feedback was asked. In the moment I wouldn't be brave to say it, but over email definitely." – Designer 3

"To get the customers to share feedback, they need to be attracted with something." – Designer 3

"I would like to get feedback, but how to bring the customer to do that, I don't know." – Designer 6

"Not that I don't care about asking for feedback, but I don't have an established after-service." – Designer 1

"When I ordered my sofa, then they asked for feedback about the customer service, but not about the sofa." - Designer 5

There's nobody to share feedback to because designer's work ends before the furniture is installed.

"I've received feedback before the furniture is installed, but that doesn't give me feedback for the concrete furniture." – Designer 3

Customers don't complain when they feel the mistake was due to their own misunderstanding.

"There's a lack of pride to admit you signed off on something you didn't understand" –Designer 2

"I wasn't going to argue or complain [about the mistakes made] because the result was nice." – Customers 1

Feedback communication is a resource to learn from.

"It's important to also hear others' feedback, because then I don't have to make an error myself to learn from it." – Designer 6

"Not asking for feedback is an unused resource, because there would be so much to learn from." – Designer 3

4.2 ASSESSING AR AND VR FOR DIFFICULTIES IN SECTION 4.1

The other focus of this research, in addition to discovering issues, was to delve into the opportunities that AR and VR technologies could offer to prevent the issues in furniture design services. RQ2 was posed to discover how the functional uses of these technologies could prevent issues disclosed in the previous chapter. The following findings display the evaluation trials conducted with AR and VR mediums, where I represented the designer's perspective, and participants employed in the study represented the customer's perspective.

<u>How do AR and VR affect the issue of *buried requirements?*</u>

The furniture in AR was a primary feedback source, that enabled real-time interaction to elicit customer preferences. Observing reactions, emotions, and body language aided to realize the participants' underlying requirements. They noted, *"It definitely helps to understand how big things are, so if I see that the sofa is too large, I won't buy it."* Using the mobile interface to visualize furniture in real space via the phone camera facilitated requirement elicitation.

Viewing virtually built room through HMD the participant looked around and explained their arising ideas on the spot using their body and hands. Developing ideas came to them by being immersed in the space and discussing their vision on what they would change: "*We could even have the kitchen separated from the room even more by a higher wall. The spatiality still adds quite a lot... maybe I can even fit my weights under the sofa.*"

The 360-degree view and placement in relation to real space helped assess fit and preferences of the furniture. Neither the AR app nor the virtual world, however, considered the body within 3D space (Figure 3.7). Placing the user next to AR furniture revealed dimensional requirements (Figure 3.8), however in a fully virtual world only built 3D models were visible to the participant, and not their own body.

How do AR and VR affect the issue of *mistargeted presentation*s?

With AR 3D furniture on the mobile screen, I didn't need to put much effort explaining the furniture, as it was comprehensible enough to not raise questions. Some degree of explanation was still necessary for understanding aspects like structure, materials, and aesthetics due to a lack of interactivity and visual quality of the model. However, the participant felt confident by noting: *"Yea, it looks pretty real to me, I can understand what it is and where it is."* The combination of being in a real space with a 3D AR furniture model facilitated clear comprehension (Figure 3.9). Since there was only one piece of furniture to evaluate, discussing the comprehension of the entire space wasn't possible. The VR space provided a clear understanding of dimensions and helped with spatial planning development. The participant expressed: "*You can tell much better where you have more space to fill",* which shows comprehension of the space and facilitates further ideation.

The visual information through AR interface and VR immersive space appeared sufficient for understanding the furniture piece, without causing confusion or an overwhelming feeling. The customer could resonate with the furniture in relation to their space but not to themselves or their body because they couldn't experience it.

How do AR and VR affect the issue of *lack of interactions?*

The AR application permitted only movement and rotation of the 3D model through the mobile interface. This interaction allowed the participant to experiment with different furniture placements. However, practical use interactions, such as sitting, eating, or sleeping, were impossible. Viewing the 3D model on the mobile interface facilitated the participant to imagine the usage by intuitively moving around the object and identifying errors. Customer feedback enabled quick adjustments to furniture placement and orientation for reevaluation. The participant found it easy to envision interaction when seeing themselves on a screenshot, taken by me, standing close to the AR furniture (Figure 3.8). Upon viewing the image, they questioned *"Is the sofa too low? I have no idea…",* which shows the potential of surfacing errors and new needs. The VR experience showed that the participant could imagine using the space and ideation on where to place their possessions: *“The functional part of me is thinking that oh, there could be a shelf of the wall here, where I can place books or potted plants or pizza recipe books.”* Having the participant in active conversation with oneself clarified that the opportunity to interact with the furniture became a priority, as aesthetic aspects were not mentioned.

How do AR and VR affect the issue of *ambiguous knowledge and terminology*?

It's possible that the participant understood certain aspects better with AR furniture without the need for me to explain using unfamiliar terms, but this couldn't be asserted definitively. From the options in IKEA Place app, some furniture-related terms were confusing for the participant: *“Wait, should I choose ‘divaanit’ [L-shaped sofa] or ‘moduulisohvat’ [modular sofa]?”*, which illustrates the problem well, however using AR to view it, did not explain the difference clearly. Participant using the HMD to evaluate the materials in VR space (Figure 3.16) expressed the clarity of furniture materials by stating “*Even a non-designer person can see that it’s a stone worktop.*” Further exploration of these potentials, however, could be conducted in a long-term project.

How do AR and VR affect the issue of *lack of independence?*

Using the AR application empowered the participant to make independent decisions and navigate the app independently (Figure 3.10), while asking for assistance only for conflicting ideas. This approach fosters a sense of responsibility, allowing them to prepare and share design ideas, which was supported by the participant’s initiation: “I will try another one.” The idea that AR application can guide users into making independent and confident decisions appeared to be fitting. The participant in the VR trial expressed a wish by seeing the cooktop on the kitchen surface (Figure 3.15), that “*If I’m a cooking enthusiast, then I’d want to have an induction stove like this, but also additionally a gas cooker as well”* which shows confidence in their wish by being able to view, understand and imagine their activities. As a designer, it's a relieving opportunity to encourage customers to 'take matters into their own hands' without the need to find other methods to probe for their needs and wishes.

How do AR and VR affect the issue of *waste of time*?

The AR trial didn't fully address the issue of wasted time in providing design solutions due to the app's limitation of placing and viewing only one furniture piece at a time. While the trial showed potential for fast intuitive decision-making and independent design changes, some scaling bugs in the AR application (Figure 3.11; Figure 3.12) were revealed, causing the participant to express fatigue: *“Eehh, I don’t feel like trying anymore, let’s get something else.”*

Using the VR space, in the context of wasting time, had a promising outlook where the participant commented: *“Optimizing the solution seems better in VR rather than if I would start to draw on paper.”* This thinking explains that the process of design development along with decision-making can be improved by using VR technology to save time.

How do AR and VR affect the issue of *limiting communication channel*?

The communication channel in this test was direct communication where the participant and I were in the same space. In the trials, AR and VR technologies functioned as tools to present and understand space, and not as communication channels, so evaluation of these technologies as communication channels could not be done. Although communication issues are not directly tied to the AR and VR technologies, they do enable saving photos of the views and sharing via email or instant messaging. The importance of the customer and designer being in the same space, however, was supported by a comment the VR participant made: “*You know what I’m looking at, you can see what I’m seeing. If I can see that the kitchen worktop is here *points at thigh height*, then it’s easier for me to tell you it should be here *points at hip height*.”* This is significant in understanding the customer might need to use their body and point at things to communicate accurately.

How do AR and VR affect the issue of *missing feedback?*

Neither the AR app nor the VR environment could be assessed for the purpose of receiving feedback for the outcome of the furniture because the furniture was not built. This subject of feedback can be tested on a long-term project where the design solution would be built in real life. However, feedback assessment for the design can be discussed. While watching furniture through the mobile interface in AR and through the head mounted display in VR, no specific methodology for practicing feedback reception emerged. Customer participation in the room design shared responsibility for the design, which relieved potential embarrassment if the client dislikes seeing the solution: *"Well, I was here to think about how the room could be, so it's not only you who created it. And if I don't like it, it's my fault as well*." The participant being in a virtually built room expressed the ease of giving feedback and discussing the space by saying: *"It* [being in a VR space] *makes giving feedback somehow tangible.*

4.3 ADDITIONAL ANALYSES

In addition to the study's main findings, unexpected insights surfaced, which were then analyzed in relation to the current topic. These insights need to be discussed in order to put the study into perspective and realize the surrounding matters.

First, this study has noted the importance of mapping requirements and using them as a basis to define a problem and lay a foundation for a solution. Surprisingly, the evidence of designers finding requirements important to deep-dive into was lacking. It could be concluded from the interviews that the motivation to elicit individual requirements is depleted to save time, energy, and resources. Designers feel tired of attempting to figure out what their customers need and catering to their changes in mind. They believe it's the customer's responsibility to structure their needs, and if that's not the case, it's more important to just get the furniture done, instead of getting it done well. They believe the mismatch between imagined furniture and produced furniture is inevitable and something that cannot be prevented unless the customer makes effort to ensure otherwise.

Second, designers and customers use photos resourced online for inspiration, and base their requirements on the concepts being fed to them. Relying on the insights from interviews, designers expect photos from customers that showcase their wishes, and customers expect photos from designers that showcase the designer's ideas. The endless circle of aesthetic priority seems to be driving interior and furniture design. Jämsén (2023) jokingly called interior designers as "Pinterest designers", which proves to be appropriate considering the accessibility of Pinterest as a platform for inspiration. Pinterest is an online platform that uses artificial intelligence to tailor recommended content (Zaratti, 2021). Designers expect inspirational photos from customers, and customers retrieve them from Pinterest. To present a spatial design concept, designers use

Pinterest to retrieve photos. This loop of Pinterest use can lock in the aesthetic focus, where individual functionality is overlooked, because Pinterest feeds popular content, that can be confused as personalized.

Third surprising result is revealed within the discussions of hypothetical use of AR and VR in interior and furniture design. Opinions on using these technologies were emotional and polarized, ranging from excitement to fear. Some designers thought that the use of AR and VR could prove to be useful in terms of testing the dimensions and use cases of custom-made furniture, not to mention the excitement of walking around in a future space. On the opposing end however, other designers find that the current practices do suffice, and that using these technologies would be “too much work” and seem overly complicated and expensive to include. Customers sounded excited over the possibility to see their future spaces with their own eyes, but at the same time found the opportunity as “premium” to customers willing to pay a high price for the service, in which they do not belong.

The fourth subject that deserves to be mentioned in additional analysis, is the problem of not only the customer imagining oneself and their body in their new furniture, but their already existing belongings. A quote by a customer *“I think it’s a typical question if my bed will fit here.”* brought attention to a problem that has not been discussed in this study, but is relevant in the discussions surrounding furniture and interior design.

4.3.1 SUMMARY OF THE FINDINGS

The following bullet list describes the summary of insights gathered from the research.

- Designers struggle to understand what customers want due to oversights and changing needs. Augmented reality and virtual reality help visualize furniture but have limits in considering the user's body in 3D space.

- Understanding custom-made furniture is hard for customers, causing confusion and challenges in decision-making. While AR and VR help understand spaces, they need explanations for details.

- Focusing on looks over practical use in design can lead to issues. Customers find it hard to imagine dimensions, which impact decision-making. AR allows movement but lacks practical interactions. In VR, participant expresses ideas confidently, improving spatial understanding.

- Explaining designs is tough for customers and highlights a need for better communication. AR aids understanding but has confusing terms, and in VR, furniture materials are comprehensible, even for non-designers.

- Customers struggle to make decisions, and designers feel overwhelmed. AR empowers decision-making, despite limitations and in VR, the participant confidently expressed preferences.

- Optimizing the design process is crucial to avoid frustration. AR has potential, but faces scaling issues. Using VR for efficiency is promising by improving design development.

- Communication challenges persist, by favoring direct methods. AR and VR help understand space but aren't clear communication channels. Sharing the same virtual space is essential to ease communication.

- Designers fear feedback due to financial concerns and avoiding negative feedback is common. There's a lack of after-service for sharing and receiving feedback. AR and VR struggle with feedback, but collaboration is facilitated. In a virtual room, giving feedback is easy, making the process tangible.

5 DISCUSSION

We cannot create better design process if we don’t know what’s wrong.

The study discussed the challenges in understanding and presenting spatial design solutions in the context of custom-made furniture. Additionally, it emphasized the importance of effective communication between designers and customers to prevent loss of resources, dissatisfaction, and damaged relationships. The goal of the research was to surface and explain problems related to presenting and understanding spatial plans and custom-made furniture solutions, with an additional focus on the emerging use of augmented reality and virtual reality technologies. The study aimed to address two key questions: the difficulties in understanding and presenting spatial and furniture design solutions, and the potential of AR and VR technologies in overcoming these difficulties. The primary objective for conducting this study is to improve interior design services by encouraging collaborative spatial design practices and incorporating stakeholder needs. Related research as well as primary research highlight the inadequacies of conventional design presentations, and the potential of AR and VR technologies to enhance spatial understanding through interactive features.

The importance and contribution of this study lies in three main aspects:

I. *Customer-Centric Design:* This aspect is crucial as it shifts the focus towards customer-centric design, allowing customers to actively participate in the design process and make independent choices.

II. *Communication Improvement:* The research aims to improve communication between customers and designers, by addressing problems and misunderstandings while emphasizing the need for customers to be well-informed and confident in their choices.

III. *Integration of AR and VR Technologies:* The emerging use of AR and VR technologies is highlighted as a potential solution to enhance understanding and provide dynamic, interactive experiences in spatial design.

To be able to improve custom-made furniture design practice, we needed to know what's wrong. The findings highlighted several challenges and nuances in the interaction between designers and customers in the context of spatial design. These included the difficulties in obtaining clear requirements from customers, inadequacy of current design presentation practices, and the importance of balancing information provided to customers. Additionally, the fear of feedback, both from designers and customers, and the challenges associated with decision-making emerged as prominent issues. The insights highlight the need for improved communication channels, the importance of acknowledging aesthetic and functional aspects in design, and the significance of feedback as a valuable resource for learning and improvement in the design process. These insights shed light on the complexities present in spatial design collaborations and underscore areas where creative interventions could lead to more effective and satisfying outcomes for both designers and customers.

To be able to improve the design practice we needed to explore the possibilities and limitations of emerging technologies. The findings from AR and VR trials highlight that they serve as valuable tools for real-time interaction and could potentially be an effective agent against the issues with the design process. However, challenges persist, such as limitations in practical interactions, terminology understanding, and usability issues like scaling bugs. Additionally, further assessment is needed for feedback reception, particularly in scenarios where furniture is already built in real life. While AR and VR technologies offer advantages in understanding customer preferences, there are important considerations for successful integration into furniture design services.

5.1 IMPLICATIONS

Navigating the complexities of this study may have led us to lose sight of perspectives by becoming entangled in the intricate web of design practices, human cognition, imagination, systems creation, and dimensional thinking. To prevent succumbing to this complexity, it is time to redirect focus towards a discussion on the broader implications of these subjects.

5.1.1 VALIDATION

- The custom-made furniture design process often grapples with unaddressed issues, such as spatial imagination skills and hidden furniture requirements, leading to miscommunications among stakeholders. Failure to understand these challenges can result in unsatisfactory outcomes, causing losses in money, time, materials, and strained customer-service provider relationships. A more comprehensive understanding of these intricacies is crucial for improving the overall process.

- The prevalent issue of prioritizing aesthetics is evident, as people often arrive with preconceived solutions without considering underlying problems. Platforms like Pinterest and the internet make this fixation on visuals worse, by emphasizing aesthetics from design stage to the final outcome. Traditional sources of design inspiration, such as showrooms and magazines, have been overshadowed by the dominance of image-centric platforms which limit the exploration of ideas. Consequently, furniture planning and purchasing decisions are primarily based on visual appeal rather than functionality or experience.

5.1.2 EXPLORATION

- The AR and VR tools hide the potential to be used in interior and furniture design by not merely showing people their new space in a 3D world, but it can be designed to be used in the requirements elicitation phase, ease decision-making and practice scenarios with using the furniture to emphasize function and interaction. The disclosed perception of using AR and VR technologies is polarized, such as too futuristic, expensive, bad quality and inaccessible, but also very cool, which marks the pain points and excitement to focus on in further exploration.

- The use of VR and AR can grow to be used commercially as a tool to communicate 3D spaces to replace images and difficult verbal explanations. It has the potential to expand to other stakeholders involved in the furniture business, such as furniture construction companies and furniture installing staff, where standard complex technical drawings can be replaced by possibilities to visit the space before real life.

5.1.3 CONTRIBUTION AND STAKEHOLDER BENEFITS

- Stakeholders can benefit by learning about the problems, which builds a problem-based foundation to try solutions on. The study findings contribute to changing the structure of the design process by disclosing what customers and designer's experience now and give way to how it could be changed. Identifying and understanding the problems in the design process is like creating a roadmap for everyone involved – customers, designers, and producers. It helps stakeholders learn about these issues and provides a solid foundation for finding solutions. By tackling the challenges first, the study contributes to making the design process less stressful and more empowering for both designers and customers.

- Introduction to the structure, processes and problems of requirements engineering in this study gives an understanding of the systems engineering concept and application possibilities to interior and furniture design. Mixing two domains in this study contributes to a wider understanding of the furniture design approaches by exploring and finding links between the two practices.

5.1.4 EXTENSION AND PERSPECTIVE

- Discovering that ideas from diverse domains intertwine well was remarkable. For example, principles used in requirements engineering also fit perfectly in spatial design practice. This blending of concepts isn't limited to work; it applies to everyday life, from utilizing services to contemplating food orders and navigating interpersonal relationships. Instead of stressing out and wasting time and energy trying to find solutions, it's better to step back and understand the problem clearly. This way, we can avoid unnecessary complications and solve problems more efficiently.

- Related research provided a wider and more focused understanding into current design practices and understanding of 3D spaces. Regardless of the expected outcomes, the study extended to other areas of problems in the practice, that cracked the door into other issues with different reasons and thus opportunities for change. The revelations give perspective to wide range of studies that could be conducted surrounding the topic of problems regarding furniture design process and service.

5.1.5 POINTS OF INTERVENTION

- Opportunity for intervention in problem domain lies in effective probing mechanisms for requirement engineering, or “how to know what people need and want? To address problems effectively, we need to better understand what people really need. Designers often miss the mark because they aren't fully aware of customer requirements and how they impact the success or failure of a design. To fix this, we should rethink how we focus on and structure these needs and usage scenarios. To uncover these insights, we can borrow ideas from requirements engineering practices. Additionally, incorporating 3D technologies like AR and VR can be a game-changer.

- Opportunity for intervention in solution domain lies in effective presentation techniques, such as AR and VR, for successful cognitive understanding and confident decisiveness, or "How to show people if this is what they need?". Additionally, empowering customers to independently use furniture presentation tools is a positive shift for designers. This means designers guide the process without bearing the entire responsibility for each design choice. To drive this transformation, incorporating concepts like co-evolution and primary generator is effective. Integrating co-evolution and primary generator concepts with 3D presentation technologies, such as AR and VR, can significantly transform the design presentation and decision landscape.

- Intervention for seeking feedback lies in reframing the issue. The issue can be approached as Dr Adam Grant explained - the emphasis should be on worrying less about the nature of received feedback, whether it's encouraging or discouraging, and instead, we should prioritize obtaining input that facilitates learning from strengths and overcoming weaknesses. A growing body of evidence suggests that requesting feedback may not be the most effective way to seek assistance. Typically, feedback elicits responses from two groups: cheerleaders applauding one's best attributes and critics attacking the worst aspects. What is truly beneficial is having a coach, someone who guides us towards becoming a better version. The key lies in asking for advice for the future rather than dwelling on past feedback. Shifting the focus from feedback to advice can yield significant improvements. Asking for advice rather than evaluations increases the chances of receiving constructive guidance focused on enhancement. (Grant & Huberman, 2023)

5.2 LIMITATIONS

Data reliability.

The concerns about the accuracy and reliability of data are present in terms of self-reported information from designers and the challenges of customers describing and evaluating presentation methods. The methods designers use to present their designs vary from the choice of practice, which shows that more thorough research on the effect of different presentation methods could be useful. Additionally, methods for how designers collect customer requirements were insufficient.

Complexity of cognitive understanding and psychology.

The discussions of cognitive understanding both in terms of what designers think their customers need and difficulties with customers trying to articulate their understanding was complex. This was a complicated topic to talk about as my knowledge of the subject is limited, and thus the research didn't reach its full potential.

Evaluation challenges.

There were challenges to the evaluation of AR and VR technologies, which included limited experience, absence of more thorough user-testing, and limitations in available possibilities to test them. Long-term studies need to be done to find the potential and problems with these technologies.

Testing methodology.

The limitations in AR and VR trials surfaced as lacking in facilitators, because I tasked myself with acting as a designer, as well as observant and note-taker. These tasks could have affected the objectivity of the trials. Regardless, the trials were conducted for the purpose of exploration and not as user-testing tasks.

False expectations.

The expectations for study results were initially mainly focused on mistakes and problems that customers that have ordered furniture have discovered after they received the furniture. The methodology to retrieve data was built around this expectation. However, while conducting the interviews the expectations changed slightly and revealed that different problems were present, but due to non-rigid questions, the interviewees were allowed to express the problems they really had, and not the ones I expected.

6 CONCLUSION

In the intricate realm of custom-made furniture design and spatial planning, this study gave me a chance to embark on a journey to unravel the complexities, challenges, and also opportunities rooted in the design process. The need for effective design and furnishing reaches all living spaces, thus making it a universal aspect of everyone’s life. The journey from concepts to real life furniture is full of potential pitfalls, as surfaced and highlighted in this study.

The foundational hypothesis of this exploration lies in the acknowledgement that while custom-made furniture aims to meet individual needs and preferences, the design process is not without its obstacles. The study delved into the experiences of designers and customers, which reveals the struggles that describe the design process. Spatial imagination skills, unconscious and hidden requirements, and miscommunications emerged among stakeholders as some of the critical issues. The conventional presentation methods, that rely heavily on 2D visuals, prove to be insufficient in conveying the dynamic and interactive nature of spatial designs. This insufficiency contributes to a bunch of challenges and consequences such as damaged relationships between the stakeholders, and the risk of wasting resources. Furthermore, from mistargeted presentations and complex terminology to the lack of interactivities and independence, the research discovered layers of challenges that demand attention and intervention. The importance of clear communication, feedback mechanisms and independent decision-making turn out to be vital components for an effective design process.

The introduction of AR and VR technologies emerge as potential game-changers in this landscape. While the technologies show promise in enhancing spatial understanding, requirements elicitation and comfort in decision-making, their integration into the service can bring forth new challenges, but also opportunities.

The study recognizes the polarized perspectives on these technologies, which range from excitement to concerns about costs, complexity, and accessibility.
As the study is concluded, it goes beyond mere search of problems, but offers insights into the potential for improvement. The collaboration of diverse concepts, from requirements engineering to spatial design practices, showcases the relationship of ideas. This blend isn't confined in this realm alone – it resonates in everyday life, where it encourages a change from exhausting problem-solving to a clear understanding of the problem at hand.

To conclude, as we navigate the intricate world of custom-made furniture, this study serves as a compass that points towards the reframing possibilities. Recognizing the issues is the first step towards innovation, and the revelations in these research findings pave the way for a positive change. When prioritizing customer-centric design, promoting effective communication, and embracing emerging technologies, the future of spatial design shows exciting promises. This is not merely a study, but also a call for action – an invitation to redefine the design presentation process, empower the customer and create dynamic and functional spaces that exceed as much, or more, as aesthetics. The journey from concepts to real life furniture doesn't need to be daunting, but instead it can be an inspiring collaboration where designers and customers come together to create spaces that resonate with individual needs and preferences. With each challenge surfaced, there are opportunities for improvement and growth in the design landscape that integrates innovation, and more importantly, satisfaction.

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8 APPENDIX

Figure 3.1. An empty room to run the AR and VR trials in; view from the doors.

Figure 3.2. An empty room to run the AR and VR trials in; view from the window.

Figure 3.3. AI generated moodboard.

Figure 3.4. AI generated moodboard.

Figure 3.5. AI generated moodboard.

Figure 3.6. AI generated moodboard.

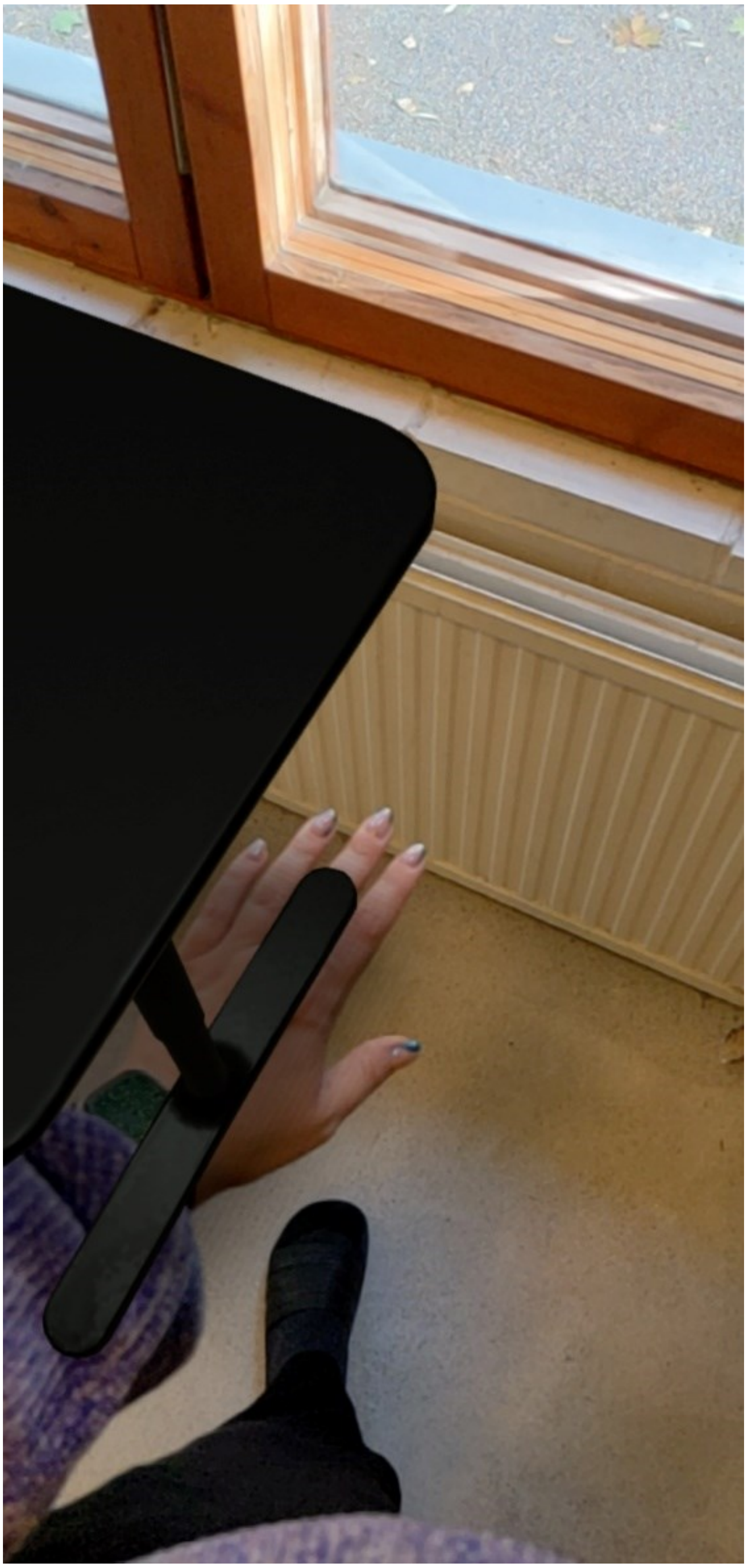

Figure 3.7. AR desk hovering on top of a hand.

Figure 3.8. AR participant standing in the trial space in relation to AR sofa.

Figure 3.9. AR stool placed next to a real stool in the trial space.

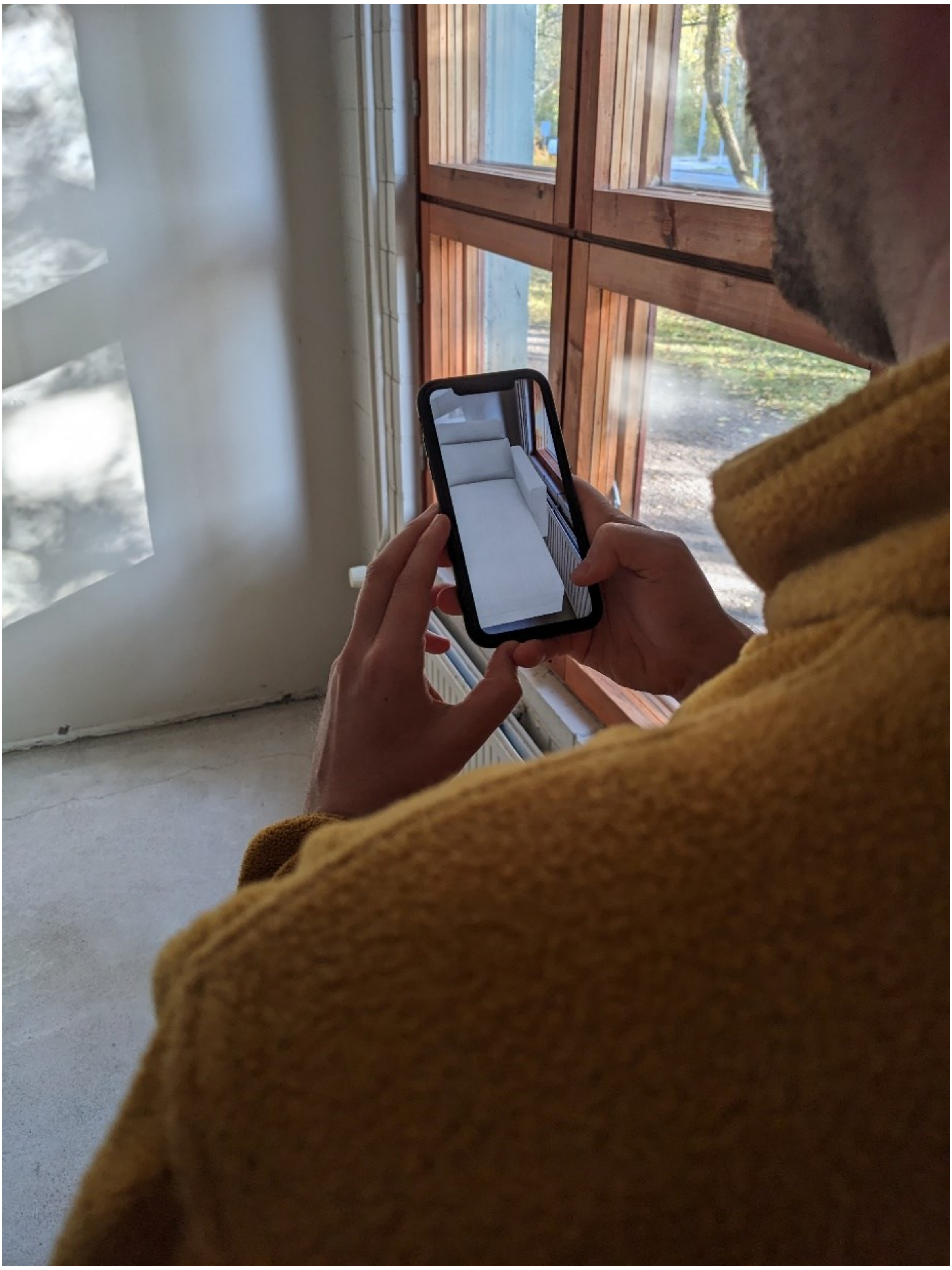

Figure 3.10. AR participant interacting with the AR application.

Figure 3.11. A screenshot of AR application with scaling issues.

Figure 3.12. AR participant holding a phone showing scaling bugs on the screen.

Figure 3.13. A virtual 3D room; view from the doors.

Figure 3.14. A virtual 3D room; view from the window.

Figure 3.15. VR participant discussing using the cooktop.

Figure 3.16. VR participant evaluating the materials.