



HAL
open science

Towards the use of virtual reality prototypes in architecture to collect user experiences: An assessment of the comparability of patient experiences in a virtual and a real ambulatory pathway

Jean-Philippe Rivière, Louis Vinet, Yannick Prié

► To cite this version:

Jean-Philippe Rivière, Louis Vinet, Yannick Prié. Towards the use of virtual reality prototypes in architecture to collect user experiences: An assessment of the comparability of patient experiences in a virtual and a real ambulatory pathway. *International Journal of Human-Computer Studies*, 2024, 192 (103342), 10.1016/j.ijhcs.2024.103342 . hal-04680620

HAL Id: hal-04680620

<https://hal.science/hal-04680620>

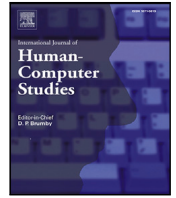
Submitted on 28 Aug 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Towards the use of virtual reality prototypes in architecture to collect user experiences: An assessment of the comparability of patient experiences in a virtual and a real ambulatory pathway

Jean-Philippe Rivière*, Louis Vinet, Yannick Prié

Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, F-44000 Nantes, France

ARTICLE INFO

Keywords:

Lived experience
Micro-phenomenological interview
Patient experience
User-Centered Design for architecture
Virtual reality

ABSTRACT

Virtual Reality (VR) enables the low-cost production of realistic prototypes of buildings at early stages of architectural projects. Such prototypes may be used to gather the experiences of future users and iterate early on in the design. However, it is essential to evaluate whether what is experienced within such VR prototypes corresponds to what will be experienced in reality. Here, we use an innovative method to compare the experiences of patients in a real building and in a virtual environment that plays the role of a prototype that could have been created by architects during the design phase. We first designed and implemented a VR environment replicating an existing ambulatory pathway. Then, we used micro-phenomenological interviews to collect the experiences of real patients in the VR environment (n=8), along with VR traces and first-person point of view videos, and in the real ambulatory pathway (n=8). We modeled and normalized the experiences, and compared them systematically. Results suggest that patients live comparable experiences along various experiential dimensions such as thought, emotion, sensation, social and sensory perceptions, and that VR prototypes may be adequate to assess issues with architectural design. This work opens unique perspectives towards involving patients in User-Centered Design in architecture, though challenges lie ahead in how to design VR prototypes from early blueprints of architects.

1. Introduction

Early in the architectural and building design process, architects try to elicit the most information they can get from their stakeholders about current and foreseen usages, as well as constraints. This allows them to anticipate how the building and the space will later serve the needs of users (Ojjevaar et al., 2009; Leicht et al., 2010). However, between the initial blueprints and the arrival of users, there can be several years of a rigid process welcoming less and less changes, because it entails more and more technically detailed versions of the plans and expensive construction. This may be a significant issue because design errors related to usage may remain unnoticed throughout the process, until users actually inhabit the building and begin appropriating it, only being able to cope with minor usage flaws. Some authors propose to tackle this issue by applying User-Centered Design (UCD) to architecture (Bullinger et al., 2010; Zahedi et al., 2011) and building prototypes to get feedback from users as early as possible.

A major difficulty with prototyping in architecture is that the building under study either does not exist or has other usages and cannot be used. To address this issue, it has been suggested that Virtual

Reality (VR) prototypes of future buildings be used to simulate the foreseen spaces and usages. Future users could then experience in VR the future buildings and give feedback to architects, possibly leading to new user requirements, designs and prototypes. Such iterations would be employed throughout the entire process, as in a classic UCD approach (Bullinger et al., 2010; Kamat and Martinez, 2001). Although the use of VR in architectural processes is not new (Bridges and Charitos, 1997), it is now mature enough to be used consistently (Dorta et al., 2016; McLaughlan and Liddicoat, 2018). VR prototypes have also been proven to be effective in immersing users in the future building and gathering their reactions or needs (Alizadehsalehi et al., 2020).

A key aspect of any approach based on getting feedback from end-users is to collect their subjective experiences (Bødker, 2006; Norman, 2002). In our architectural case, it means collecting the experiences of users interacting with VR prototypes of buildings, that could be used as surrogates of the actual experiences users would live within the real buildings, for architects to learn and iterate from them. However, and this is our general question, it remains to be seen to what extent

* Corresponding author.

E-mail address: riviere-jp@univ-nantes.fr (J.-P. Rivière).

<https://doi.org/10.1016/j.ijhcs.2024.103342>

Received 12 July 2023; Received in revised form 10 June 2024; Accepted 20 July 2024

Available online 7 August 2024

1071-5819/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

experiences lived in VR prototypes of buildings are similar to real-life experiences.

To address this question, we worked with an architecture agency specializing in healthcare facilities, that wanted to explore how to leverage the experiences of a specific user group—patients—right from the early stages of the design process. We took advantage of the fact that the agency had redesigned an ophthalmologic ambulatory surgical pathway of a clinic a few years ago to compare experiences in the real building and in a virtual environment.

More precisely, our main research question (RQ1) is related to the extent to which the experiences lived by patients in a VR environment simulating an ambulatory pathway are similar to the real-life experiences of patients in the actual pathway. We designed and implemented an immersive VR environment replicating an existing building and an ambulatory pathway, that could act as if it was a VR prototype of a future building. We used an innovative micro-phenomenological approach to describe and compare the experiences of real patients in this VR environment and in the real pathway. We conducted micro-phenomenological interviews to collect lived experiences of patients both in our virtual prototype (n=8) and in the real pathway (n=8). We also collected VR traces and videos. We modeled all these experiences as sequences of moments described by categories. We then normalized the categories in order to assess the similarities and differences of experiences between groups, both globally and for specific moments. Our results suggest that patients live comparable experiences along various dimensions of experience such as thought, emotion, sensation, social and sensory perceptions.

We had a secondary research question (RQ2) related to understanding if the issues of the real ambulatory pathway could also be assessed in VR. Our study shows that VR prototypes may actually be adequate to assess issues with architectural design at an early stage.

This article is organized as follows. First, we focus on related work on prototyping using VR in architectural design, before discussing the various dimensions of lived experience and the comparison of VR and real-life experiences. We then describe the rationale of our study, and the choices we made to design our VR environment replicating the ambulatory pathway. Afterwards, we describe our micro-phenomenology-based methodology for comparing lived experiences in VR and reality. Next, we present our results on the similarities and differences of VR and reality experiences. Finally, we discuss the value of VR prototypes in architecture as well as directions for future work.

2. Related work

2.1. UCD and VR experience prototypes

User-centered design encompasses both a design philosophy and a variety of methods (Abrás et al., 2004) that share the overall aim of putting end-users at the center of a creation process. What is essential to any UCD practice, according to Abrás et al. (2004), is the design and testing of prototypes. Houde and Hill (1997) define a prototype as “any representation of a design idea, regardless of medium”. It is a limited version of a product or an artifact (Abrás et al., 2004) generally created to answer questions (Wall et al., 1992). Houde and Hill’s model defines three general purposes of prototypes: testing the *role* of the future system (Is my idea useful for users?); probing its *look and feel* (What do users feel and experience when using my system?); and testing the possibility of the *implementation* of an idea (Is my idea technically feasible?). Lim et al. (2008) extended the model, arguing that prototypes also support design work, allowing designers to explore design spaces, generate ideas, and communicate with team members. In this direction, Buchenau and Suri (2000) propose to design around the experiences designers want to induce with their product. This process, known as “experience prototyping”, encompasses all the methods used to simulate important aspects of the future user experience into a prototype.

Prototypes can have different degrees of fidelity, related to their similarity to the final products (Rudd et al., 1996). McCurdy et al. (2006) propose to assess the fidelity of a prototype along 5 characteristics: the level of visual refinement, the breadth of functionality, the depth of functionality, the richness of interactivity, and the richness of data model. While low-fidelity prototypes can be used early to engage and iterate with users (Walker et al., 2002) as well as to quickly evaluate usability (Virzi et al., 1996), high-fidelity prototypes are particularly useful to test the look and feel of a final product (Rudd et al., 1996) and conduct extensive evaluations (Nielsen, 1990).

Virtual reality is a great tool for producing prototypes and conducting user-centered design processes (Müller et al., 2016). As traditional prototypes (paper, video, screen-based, etc.), VR prototypes can be used to collect and check the expectations of customers (Zimmermann, 2008) and foster collaboration between users and designers (Mei et al., 2021). But where they particularly shine is in their ability to simulate real-life environments and reduce the costs associated with real-life prototypes development (Delarue et al., 2006). VR is a great tool to “simulate situations that would otherwise be difficult or impossible to achieve in real life” (Xu et al., 2021). A notable example of this is the study by Reinschuessel et al. to test different interaction techniques in an operating room with surgeons (2017). Faced with the challenge that medical facilities are sterile environments with strictly regulated access, they created a realistic operating room in VR to do so. VR prototypes are also effective when it comes to reducing costs. For example, Delarue et al. (2006) argued that creating VR prototypes of an assistive robot is less expensive than implementing a real robotic prototype. They proposed a UCD method where new features are designed, implemented and tested in VR. The features that best meet the user’s needs are then implemented in the real robot.

In this work, we created a VR environment by simulating an existing building. This environment was intended to play the role of a high-fidelity experience VR prototype that architects could have constructed at design time so as to get early feedback from their users.

2.2. VR prototypes for UCD in architecture

The introduction of Building Information Modeling (BIM) changed the way architects design and work today (Azhar et al., 2012). BIM involves both the creation of digital models of physical environments and a collaborative platform where all stakeholders can work together (Doan et al., 2019). The National BIM Standard argues that digital mock-ups are essential for fostering collaboration among stakeholders at different phases of the life cycle of a facility (National BIM Standard-United States, 2015). Still, Oijevaar et al. (2009) pointed out that end-users remain very little involved in architectural design processes, and researchers started to explore the use of immersive technology—mostly VR—, to conduct UCD (Alizadehsalehi et al., 2020; Davidson et al., 2020).

VR can be mobilized to analyze and address issues before the construction phase (Heydarian et al., 2015): VR prototypes allow end users to experience buildings early in the architectural design workflow and provide feedback. For example, it has been shown that health professionals can spot architectural flaws in virtual environments (Leicht et al., 2010) and that feedback obtained in VR is likely to concern the appearance of the building and how participants *felt* in it (Lim et al., 2008). Moreover, Bullinger et al. (2010) showed that VR could foster architects/users collaboration and contribute to an increase in the quality and performance of projects. It seems clear that VR prototypes can play a prominent role in allowing architects to conduct UCD. Yet, as Bullinger et al. (2010) pointed out, there is a lack of formalized assessment of User Experience (UX) in VR prototypes.

In that direction, Kalantari and Neo (2020) investigated in their meta-review the current challenges, effective practices, and future directions of using fully immersive virtual environments in interior design research. They found that the essential aspects of a successful prototype

were the realism of the environment, the visual and audio immersion provided by the device, and the feeling of presence (see Section 2.4). Their design recommendations were to design task-based scenarios, align VR experience to real-world experience, and calibrate systems with pilot testing. We chose to adopt this approach in designing our VR environment, as it offers good practices for ensuring a strong sense of presence: we created a 12 steps task-based scenario from the real ambulatory pathway and building, and iteratively tested our environment with “normal” users before using it with real patients.

2.3. Dimensions of lived experience

Lived experience can be defined as “*what a singular subject experiences at a given moment and in a given place: what he accesses in 'first person'*” (Depraz et al., 2003, p. 15). Understanding what constitutes a lived experience is based on trying to access and describe it later. It includes perceptions, emotions, thoughts, actions, etc.

Numerous studies have aimed to understand and classify the various aspects of lived experience. Brakus et al. (2009) proposed five dimensions based on a literature review of the work of the philosopher John Dewey, cognitive scientists, and management thinkers. Those are the sensory (experience of stimuli delivered by senses, such as visual, auditory, kinesthetic), affective (feelings, emotions, sentiments), intellectual (mental processes, such as inner speech, thoughts), behavioral (performed motor actions and behavioral responses), and social (interactions and relationships) dimensions. Depraz et al. (2017) studied how depressed people experience surprise, and proposed to categorize lived experience into 9 dimensions: Perception, Kinesthesia, Imagination, Cognition, Emotion, Volition, Inner speech, Verbal reaction, and Surprise. Heavey and Hurlburt (2008) studied the lived experience of college students using Descriptive Experience Sampling. They found five frequently occurring categories of lived experience: inner speech, inner seeing, unsymbolized thinking, feelings, and sensory awareness. It seems that the dimensions presented by Depraz et al. and Heavey and Hurlburt are a refinement of the experience model of Brakus et al. (2009). Inner speech and Inner seeing correspond to talking or seeing “in the head” and are parts of the larger *intellectual* dimension. The same goes for the dimensions of imagination, cognition, volition, and unsymbolized thinking (which could refer to the act of thinking internally). Finally, the behavioral dimension encompasses verbal reactions, while the affective dimension includes emotion, surprise, and feelings.

Classifications of lived experience should not obscure what people actually live. Pettimengin et al. (2019) warn against top-down approaches, arguing that starting from predefined structures could be detrimental to acknowledging the richness of participants’ data. We aimed to avoid preconceived structures of lived experiences, because we could not predict what patients would go through before the experimentation. We decided to let the data drive the results by conducting a bottom-up analysis, examining the experiences of each participant before defining any categories.

2.4. Comparison between VR and real experiences

Presence in VR is defined as the “*subjective experience of being in one place or environment, even though one is physically situated in another*” (Witmer and Singer, 1998). Presence derives from immersion and interactivity (Walsh and Pawlowski, 2002; Fuchs, 2006; Mütterlein, 2018), which are, respectively, the users’ ability to interact with the environment (manipulate objects, move either physically or by navigation or teleportation), and their subjective ability to influence it. A high sense of presence seems a prerequisite for comparing VR and reality (Meehan et al., 2002; Narciso et al., 2020). Indeed, if one does not feel present in VR, if what is done and experienced does not appear sufficiently real, then there is no point in comparing this experience to another experience in reality.

A considerable amount of literature has been published on the similarity between user behaviors or physiological responses in VR and in reality, during the accomplishment of specific tasks. We illustrate this with a few examples: Heydarian et al. (2015) investigated the similarities between performances of users on a set of everyday office activities (a reading task and an identifying task) in VR and reality. They found that participants could read and count similarly in the same lighting conditions. This suggests that VR can effectively simulate indoor environments and trigger user behaviors similar to those in real-life settings. In terms of physiological responses and behavior, Kalantari et al. (2021) showed that cognitive tasks in VR can provide physiological measures similar to those in real life. There is also strong evidence suggesting that physiological measurements of stress may be similar in VR and reality (Meehan et al., 2002). Finally, Seymour (2008) showed that medical motor skills learned in VR by surgeons can be transferred to a clinical setting, and vice-versa (Seymour et al., 2002; Seymour, 2008). Together these results provide insights into how VR environments can be used to train users with skills that are maintained in reality, as well as study their behavior as proxies of behavior they would have in reality.

However, the similarities between participants’ experiences in VR and reality are unclear (Kuliga et al., 2015). This question requires to specifically compare lived experiences, on tasks that are deemed similar. Many studies used questionnaires to evaluate UX in VR and reality, such that of Wagler and Hanus (2018), who studied the experience of tourists with a 360-degree VR video, a traditional 2D video, or a reality tour. 360-degree videos induced the same emotional engagement as reality, while 2D videos did not. Igarzábal et al. (2021) confirmed that the experience lived in a virtual waiting room is similar to that lived in a real one in term of boredom. Hong et al. (2019) studied the satisfaction of people in virtual and real buildings with respect to varying window sizes. They compared the sense of visual comfort, privacy, openness, and inner space, concluding that VR environments are adequate representations of the physical world. Kuliga et al. (2015) explored the UX of a building in real and virtual conditions with a 19-items questionnaire. They found no statistical difference between experiences lived in reality and in VR. In all these studies, experience-related data is collected on the basis of physiological measures or questionnaires. Although questionnaires are great tools to measure and quantify chosen aspects of UX, they impose predetermined concepts, which can prevent users from expressing the full nuance of what they have experienced (Light et al., 2010). They also lack the richness and details that characterize qualitative data (Swallow et al., 2005). To the best of our knowledge, no study aims to compare real-life and VR lived experiences, in all their richness, as we propose with the micro-phenomenological approach. Such method for collecting and comparing experiences is rather new, and has never been used to compare experiences lived in VR and in reality. We thus explore a somewhat unmapped area, both trying to answer our research questions and assessing the value of the method.

3. Design rationale of our study

Architects can use experience prototypes to explore design ideas with future users at different moments of the classical building life cycle, mainly during “preliminary design” and “design engineering” steps. Here we were interested in early stages of the design process, and our main objective in this study was to assess the kind of experiences that a high-fidelity VR experience prototype could induce in users, compared to what a real building and process actually induced. It was therefore necessary to compare the “real” experiences of users in a real building with real processes with those lived in a VR environment that simulates the real building. For this study, we needed to use a VR environment that played the role of a VR prototype that architects could have created during a preliminary design phase.

Since we could not redo the design process with architects and because the VR environment had to be based on a real situation, we

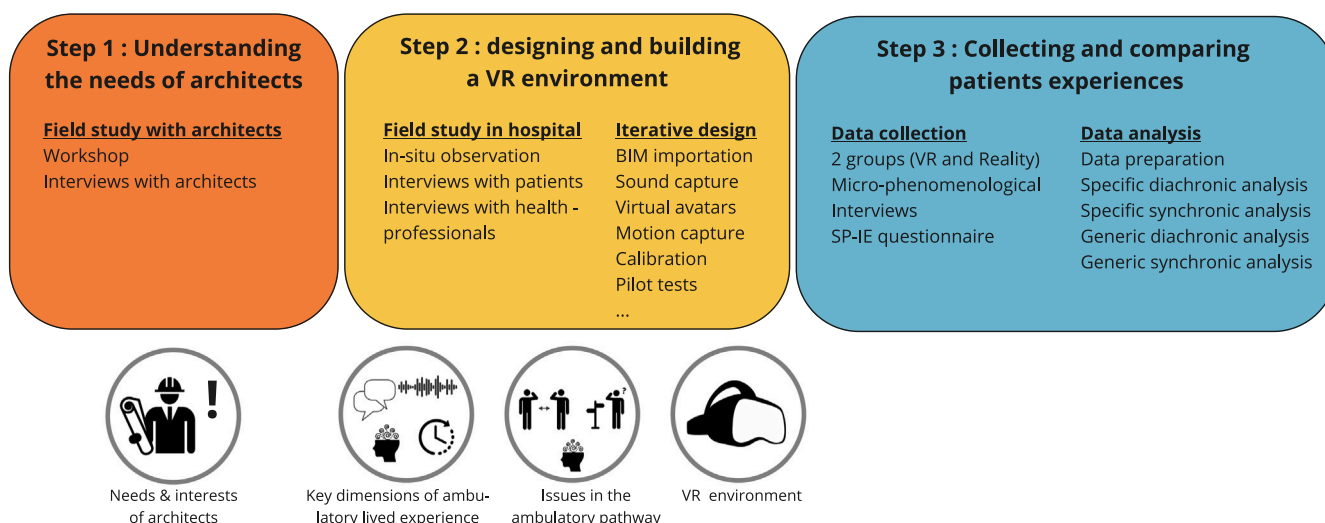


Fig. 1. The different steps of our study. The results and artifacts resulting from each step are represented by circles.

needed a real building from which we could build it. The corresponding VR environment would be built to be as close as possible to reality, while being at the same time adequate for providing the insights architects would like to get about users experiencing their design. It should be underlined that this process corresponds by no means to the task architects would need to perform to create from scratch a VR prototype, as they would first have to design the pathway and the building, and not replicate something that already existed. However, this does not represent a problem here, as we are interested in assessing the dimensions of experience that such types of VR prototypes can induce, and not in the design process of pathways and buildings by architects. We will get back to the implications of such an approach in the discussion.

3.1. The target building and processes

Our partner, the architectural firm AIA Life designer¹, gave us the opportunity to work on a large renovation project they had carried out a few years earlier in a private clinic. For healthcare facility design projects such as this one, at least two types of users are usually considered: patients and health professionals. Health professionals are generally involved at various stages of revision. However, this is not the case for patients, who usually use the building for short time periods, from a few hours (e.g., for a meeting or ambulatory surgery) to a few days (e.g., for major surgery or giving birth). Though very important,² their experiences are much more difficult to collect, making them only considered indirectly at design stage. This was a concern to the architects, that is why we chose to primarily focus on the collection and the comparison of the experiences of patients.

Regarding the choice of the facility, we focused on the indoor ophthalmology pathway for several reasons: a BIM model was available and could be used to generate the VR environment; patients live a complete care circuit during a few hours, with a rich panel of situations, which we could reproduce in VR; the ambulatory pathway was fully

operational (40 to 100 surgeries are performed each day). Also, the initial project was considered a success and all stakeholders were willing to participate in the study, notably the clinic directors and the physicians. In particular, physicians agreed to participate in the recruitment process of patients who were taken care of in the building, so that we could collect their lived experiences.

3.2. Overview of the study

Our study went through three main steps (Fig. 1). First we had to understand the information needs of architects at design time, with regards to the experiences of their users (here patients), that prototypes of future buildings could allow to collect. Next, we designed and built a VR environment meant to mimic what a high-level prototype created by architects during the design phase might look like. For this we studied the pathway itself and decided on what would be the features of the VR environment that would simulate it. We conducted a field study that allowed us to understand and model the pathway while identifying key aspects of related patient experiences. The needs of architects and those key aspects gave us requirements that we followed to iteratively build our VR environment. Finally, we collected experiences of real patients in both the VR environment and the real ambulatory pathway and compared them. We selected micro-phenomenology as our method for collecting experiences as it effectively captures sensory, affective, intellectual, behavioral, and social dimensions of lived experience. We also chose to model the unfolding of the participants' experiences in a structured way which allowed us to systematically compare description of experience between participants and between groups.

In the remainder of this article we describe these various steps and our results, and we discuss the value of the VR environment we designed, as well as the possibility of using VR prototypes at architectural design phase to get access to the experiences of future users.

4. Architects' 3D use and needs

Our first step was to understand how architects use VR and 3D models, and what questions they have regarding patient experiences so as to collect their needs with regards to VR prototypes they use at design time. First, we hosted a workshop to identify the company practices in integrating user experiences. We found three main groups of users: health professionals (physicians, nurses, etc.), health managers (directors of the hospital, etc.), and patients. We found that architects

¹ <https://aialifedesigners.fr/>

² Patient experience —what patients live and learn during their healthcare pathways— has been deemed an indicator of quality of healthcare (Doyle et al., 2013) that is increasingly taken into account by healthcare organizations (Wolf, 2015). Harnessing patient experiences in the design processes of healthcare interventions, such as architectural projects, may lead to overall better patient experiences after deployment.

usually only talk to health professionals' representatives and health managers during the design phase but never with patients. This confirmed our aim to focus on patients' experiences for our study, as it is simply not considered.

We continued our investigation with a series of 11 semi-structured interviews with architects. We focused on the problems they face during the design phase and on their needs with regard to patients experience. We followed the Critical Incident Technique of Flanagan (1954), also asking them to bring and show us during the interview their different plans, presentations, models, etc. Each interview lasted 60 to 90 min, was audio recorded and we took extensive handwritten notes. We identified themes in our notes and then listened to the audio to confirm them.

Use of 3D models by architects. Architects reported using 2D and 3D computer-aided design tools throughout their architectural projects. Different tools co-exist among the team depending on their specialization (interior designers use SketchUp³ and architects Revit⁴). During the preliminary design phase, 2D plans are mandatory and 3D BIM models are created in most cases. Multiple architects collaborate asynchronously on the same 3D models. First, the general aspects of the building are modeled (facades, interior walls and elevators). Then, at the design engineering phase, the engineers take the 3D models, transform them into 2D models, and work on technical drawings. During these two phases, architects organize team meetings during which the BIM model serves as a medium for discussion. In these meetings, a 2D screen is used to navigate into the BIM and to discuss the design.

Use of VR models by architects. VR is rarely used in the design process because it is more time-consuming than with classical screens, as the team has access to only one, computer-dependent, VR headset. VR models are produced with the Enscape software⁵, at the instigation of the designer of the team and usually appear at the end of the design engineering phase. The designer usually starts by exporting the BIM produced by the architects, then reworks it in Unreal Engine (a video game engine) to produce a highly realistic VR-compatible 3D model.

Such models are used in two ways. First, several architects experience them during team meetings and give their comments and suggestions for modifications. Architects reported that VR prototypes allow them to immerse in their plans and give them another vision of the ambiance, materials choice, patient pathways and orientation, or space size. For example, an architect immersed in a VR 3D model reported finding all the spaces smaller than he imagined. Another commented that VR allows him to see things that are invisible on a 2D plan (e.g., dimensional errors). All the problems highlighted during the meetings are considered by architects in the next iteration of their design. Second, VR prototypes can be used as a communication tool with health professionals, for example, to publicize the project or show the concept stages. However, VR is not used to design with them to avoid too high expectations for the future building. Instead, architects prefer using videos and slides during such design workshops.

Architects' needs with regards to patient experiences. When constructing a health facility, the architects reported that the experiences of patients are somehow gathered through the mediation of health professionals and never from the patient themselves, which was considered a drawback. Yet, while they acknowledged the significance of incorporating the experiences of patients into the design of healthcare pathways, the architects underlined that they face many challenges to integrate such practice into their workflow. Indeed, from a pragmatic perspective, architects do not know how to recruit patients, how to run workshops with them, how to gather their experiences, and whether the ideas they come up with will be generalizable. Their needs associated with patient experience are:

- **Understand the feeling associated with a space or a moment.** The architects emphasized that the way a space is designed strongly influences how it is felt. They want to understand the aesthetic feeling and how the ambience is experienced, as their intention is to transform (by changing lights, colors, furniture, etc.) the hospital into a more welcoming and comforting environment for the patients. They are, for instance, interested in the first impressions of patients when entering the different rooms in the pathway or if they experience more or less stress in a waiting room. By gathering and leveraging such data, architects hope to be able to propose buildings that provide a better patient experience during care.
- **Understand the orientation of people in the building.** Circulation in a health facility is crucial as it conditions both professionals' work and patients' flow. However, architects reported that the patient side of the circulations (especially signage) is often a neglected and undervalued work for their clients. This concerns understanding patient flows, how they move through space, how they find their bearings, and how they experience signage (e.g., where people naturally move towards, what are the eye-catchers).
- **Understand if confidentiality is met.** Architects see confidentiality as an important issue in healthcare facilities. They would like to understand how patients feel about the space regarding privacy or vulnerability and whether their exchanges with professionals are respected. This involves a sound aspect (e.g., what sounds are heard and how they are perceived by patients).

During the design process of a new building, these needs transform into challenges for architects. Indeed, incorporating considerations on privacy and on the emotional impact of a space necessitates direct engagement with real patients. We used these needs as guiding principles for designing our VR environment and defining the moments in the pathway we would be focusing on.

5. Design of the VR environment

The second step was to design a VR simulation of the ambulatory pathway, that would correspond to what could have been built by architects to get insights on their design from the experiences of real patients. Here, we present the pathway in more detail, and the choices we made to design the VR environment.

5.1. Case study: an ophthalmologic ambulatory pathway

Among recent projects from the architecture agency we worked with, we chose the one developed for the private clinic Jules Verne⁶ and the "Institut Ophtalmologique de l'Ouest"⁷ (a center of excellence for the treatment of eye diseases and surgery in France). In 2016, the agency was chosen to renovate a building wing that would house the clinic's new ophthalmological surgery outpatient track. They also had to work on indoor design and outpatient circuit, for which they received precise instructions, for example, they had to keep the flow of patients smooth while maintaining a pleasant and effective workspace for health professionals. They imagined a circuit which is reflected in walls' positions, interior design, the absence of hallways, open space areas, "boxes" (where patients rest and/or wait) placements, and specific care practices.

Fig. 2 represents the complete ophthalmologic care pathway that includes the ambulatory pathway. Prior to surgery, patients undergo a diagnostic process, schedule the surgery, and consult with an anesthesiologist. On the day of surgery, the surgical procedure itself lasts

³ <https://www.sketchup.com/>

⁴ <https://www.autodesk.com/fr/products/revit/>

⁵ <https://enscape3d.com/fr/>

⁶ <https://www.cliniquejulesverne.fr/>

⁷ <https://www.institut-ophtalmologique-ouest-jules-verne.fr/>

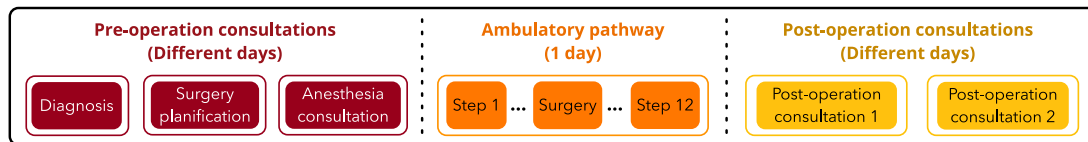


Fig. 2. The full ophthalmological care pathway. Patients undergo three stages: Three mandatory pre-operation consultations over different days, the ambulatory surgical pathway, and two post-operation consultations.

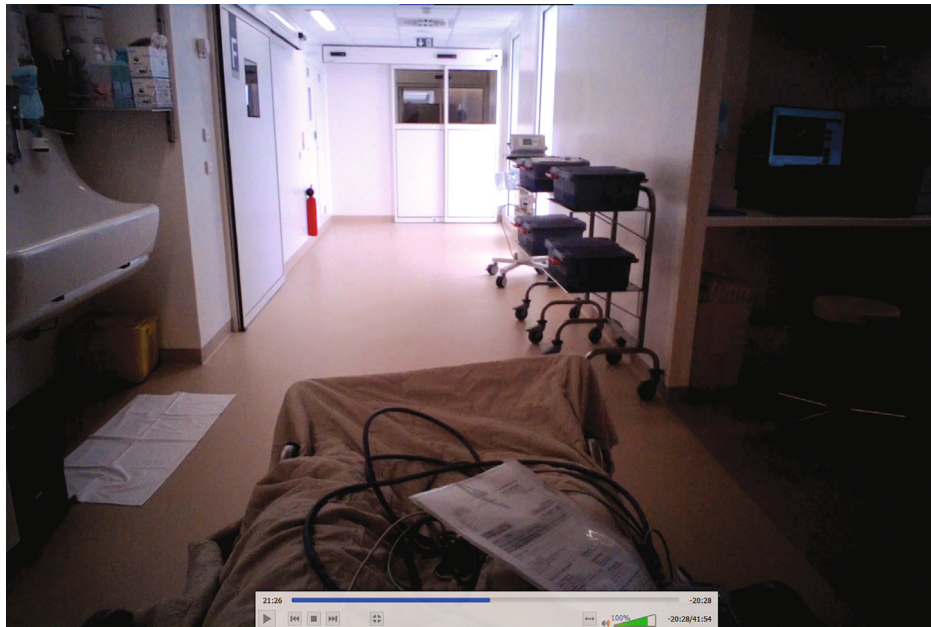


Fig. 3. A screen capture of the first-person video shot with camera glasses during the field study. One of the authors took the role of a patient and underwent the entire ambulatory circuit (except for the surgery).

between 2 to 10 min. for minor operations, but patients are required to be present for 2 to 4 hours due to preparation, administrative tasks, waiting periods, postoperative monitoring, etc. After surgery, patients must attend two follow-up consultations at the clinic after 1 and 4 weeks to assess the outcome.

5.2. Field study: Journey map and key aspects of patients’ experiences

We wanted our VR users to follow a task-based scenario corresponding to the real activity of the ambulatory circuit, so that they experience both the building and the activity that takes place in it. That is why we needed to understand and document the ambulatory pathway; to detail the tasks of patients and professionals and the steps of the pathway; and to assess what patients experience within it, so as to identify some key aspects. To do this, we carried out a field study in the hospital. One of the authors immersed himself in the hospital for four days, and conducted several *in-situ* observations.

We started with an observation (fly on the wall type) within the pathway. We followed two patients through their ambulatory process to understand the different steps of the circuit. Then, we performed a first-person “simulation” of the pathway, where one of the authors played the role of a patient and went through the ambulatory journey

while wearing camera glasses⁸. It resulted in a first-person video of the pathway (depicted in Fig. 3), which was useful for the design and development of the VR environment.

Then, we conducted six semi-structured interviews with health professionals (20 min. each) about the ambulatory pathway and the experience patients have in it. We also conducted five semi-structured interviews with patients who had followed the pathway (30 min. each), exploring “key” aspects of their experiences. We completed our data with an observation session during a preoperative consultation with one patient, which allowed us to better understand the surgery preparation context. All participants (patients and health professionals) consented to participate in the study and signed a consent form before each interview. They were not compensated for their participation. We took handwritten notes and all interviews were audio recorded.

The results of this exploration produced a detailed journey map of the ambulatory pathway and a set of important aspects of the ambulatory lived experience that we needed to implement and focus on in our VR environment design.

⁸ Tobii Pro Glasses 2 Integration Edition: <https://www.tobii.com/products/discontinued/tobii-pro-glasses-2>.

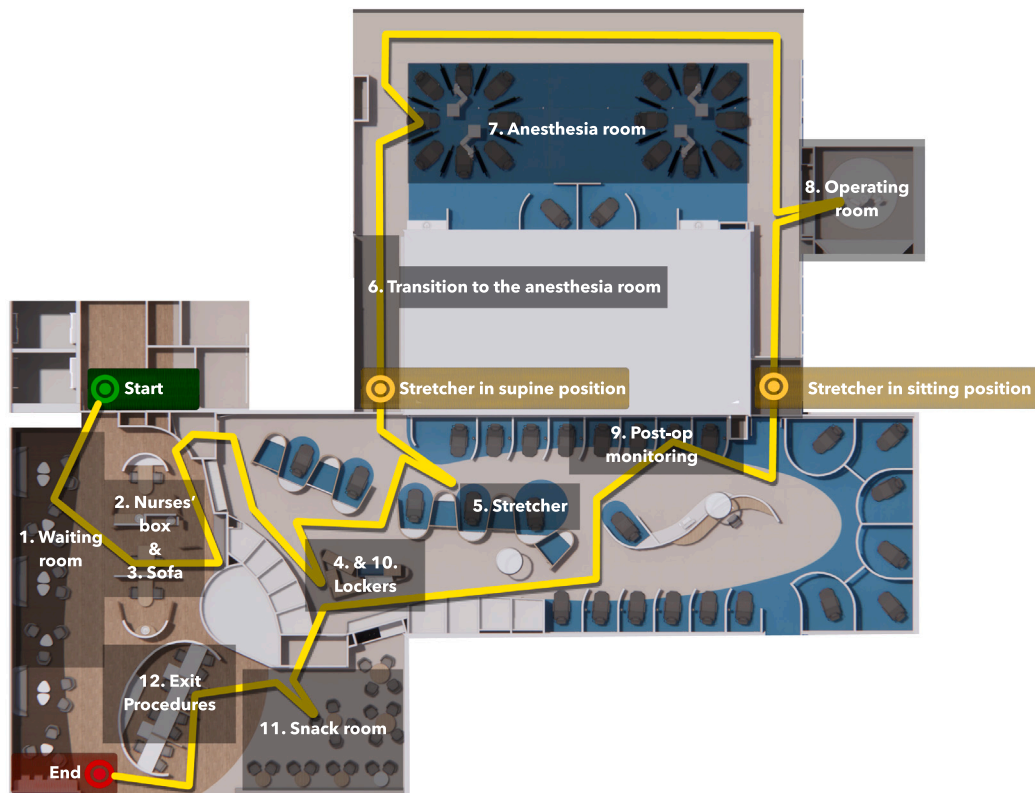


Fig. 4. Map of the ophthalmologic ambulatory service. On the same day, patients follow a 12-step circuit (yellow line). The ambulatory journey begins in the clinic's waiting room (Step 1). Once called by the nurse, patients proceed to pre-operation admission (Steps 2 and 3). Following this, they are asked to change (Step 4) and sit on a stretcher. In this stretcher, basic medical procedures such as blood pressure monitoring and catheter fitting (Step 5) are carried out. Upon completion of advanced medical check-ups, patients are transported to the anesthesia room through a corridor, where the stretcher is laid down. After anesthesia (Step 7) and subsequent eye surgery (step 8), the stretcher is raised, and patients are brought back for a 30 min. long post-operation monitoring (Step 9). If there is no issue, patients are guided back to the locker room where they dress, and walk to a snack area for refreshments (Steps 10 and 11), before exit procedures (Step 12). *Image used with permission.*

The journey map. We divided the ambulatory pathway into 12 steps, as shown in Fig. 4. Each step is described in a journey map by: its name and duration; the position of the patient (sitting, standing or lying); results from the observation (attitudes, point of view, actions and dialogues, etc.); general comments about the atmosphere (lights and sounds, healthcare work, other patients, etc.), and interactions between patients and health professionals. For example, during the waiting room step (first step), patients interact with a terminal where they provide information about themselves. They receive a ticket with a number and then sit in a chair and wait there until their number is called. They wait between 10 min. and 2 hours. There is limited interaction between health professionals and patients. The waiting room is very luminous, with large windows overlooking a parking area. Radio can be continuously heard. Other patients pass through the area when they leave the pathway, a variable number of other patients also wait for surgery with their relatives. The journey map served as the primary tool for the programmers to implement the VR ambulatory circuit.

Key aspects of ambulatory lived experience. We extracted from the interviews of patients four key aspects of patients' experience of the ambulatory pathway:

- **Perception of health professionals activities.** The perception of professionals' activities by patients is based on sound and vision. It contributes strongly to the way patients experience the medical context. Sound is especially crucial all along the circuit as vision can be impaired by lying position or disabilities. Most of the steps take place in open spaces, which encourages communication between professionals (checking the patients

and communicating with them is easy). However, a drawback is that patients can hear the conversations and chitchats of professionals, which was reported as confidentiality and noise issues.

- **Interaction with professionals and the environment.** Patients rely heavily on professionals all along the circuit. Dialogues and interactions with professionals are systematic and provide important information to them, such as directions or instructions. Moreover, patients reported interacting with different objects all along the ambulatory pathway, such as their patient records, a ticket machine, sensors of all kinds, etc.
- **Anxiety during waiting times.** Patients are anxious during the circuit. The more they wait, the more their stress increases. Stress involves the fear of feeling pain, of the unknown, of care errors, or of a post-surgery disability.
- **Change of posture and point of view during the circuit.** At the beginning of the circuit, patients are standing, later they are installed on a stretcher that can change position to become the operation table. Patients pass from sitting to lying position, are operated, then later sit, and stand up again. This conditions what patients can see and hear during the circuit and how they locate themselves in it. For example, in a lying position, they looked at the ceiling and reported losing their landmarks: "We are lying down, so we do not realize much anymore, we are passing through corridors". Patients indicated that this change of point of view is an essential aspect of their experience.

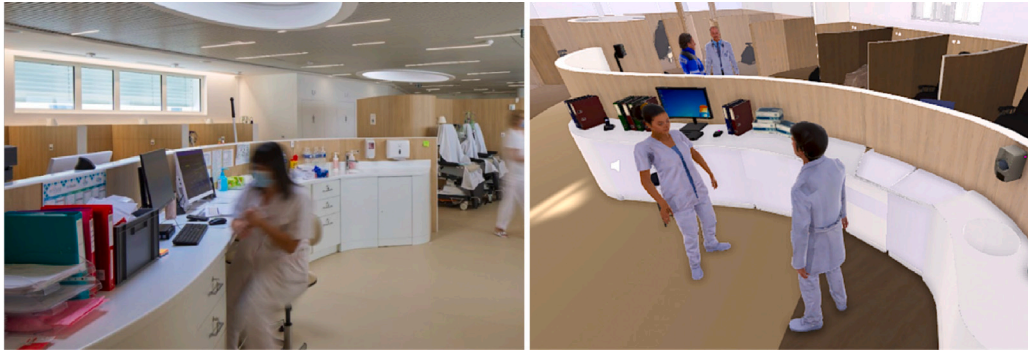


Fig. 5. Real (left) and virtual (right) installation room of the patients in the ambulatory pathway.

5.3. Design of the VR environment

Ensuring a sufficient level of presence is important for comparing experiences in VR and in reality. This means that a general requirement is to design a VR environment that is sufficiently immersive and interactive, as well as realistic. We also identified a set of 9 requirements for what we needed to reproduce or simulate in VR, both from the architects' needs and the key aspects of patients' experiences.

Architects need to understand the feeling associated with a space or a moment, that is why we needed to *Reproduce the full pathway spatially and chronologically* (req. 1). Architects also need to understand the orientation of people in the building, requiring us to *Simulate the real signage* (req. 2) and *Choose a locomotion technique that enables users to move within the hospital* (req. 3). For gaining information about confidentiality, it is important to *Reproduce all spaces* (req. 4) and *Reproduce the sounds heard in all spaces* (req. 5).

Patients highlighted some key dimensions of their experiences (see section 5.2). The first one was related to the perception of health professionals activities, which led us to *Reproduce health professionals and their actions with virtual avatars* (req. 6). Another had to do with the interactions, notably with professionals who serve as guides throughout the circuit, and patients they can interact with or observe: we had to *Reproduce interactions with health professionals and the environment* (req. 7). Two others dimensions dealt with the anxiety during waiting time, and the importance of the change of posture and point of view throughout the circuit, that is why we had to *Reproduce waiting times* (req. 8) and *Reproduce the change of posture and point of view related to the stretcher* (req. 9).

From the BIM to a VR model. We recreated the building's structure by importing the Building Information Modeling (BIM) mock-up of the clinic's wing provided by the architects into Unity⁹. This allowed us to spatially reproduce the circuit (req. 1), as well as all the spaces of the ambulatory pathway (req. 4). We optimized the model by merging all the sub-meshes into a single one using a 3D design software¹⁰. After adding light sources to the scene, we placed 3D models such as water bottles, sheets, files, etc. as well as the signage of the area retrieved from the original sources (req. 2). Once the building was ready, we implemented the ambulatory circuit chronologically (req. 1) by recreating the 12 steps of the pathway at the exception of the surgery (see Fig. 4).

Locomotion. We considered three locomotion types for patients to be able to move freely within the VR building as they would in reality: motion-based, controller-based, and teleportation-based (Boletsis and Cedergren, 2019). We discarded walking in place as it could be exhausting for elderly patients. We privileged controller-based locomotion over teleportation, so that users could keep visual contact with the environment, and experience circulations while moving (req. 3). However, as it may induce motion sickness (Boletsis and Cedergren, 2019) we implemented a reduction of the field of view when moving (Lim et al., 2021). As using a joystick could be complicated for VR novices, we created a tutorial to train participants to move around and to assess that patients did not suffer from motion sickness. Because participants of the study were elderly people and the VR passage lasted 35 min., we chose to seat participants in reality, even if they were standing in VR, as it would cause less fatigue than standing (Chester et al., 2002) and induce less sickness (Merhi et al., 2007; Zielasko and Riecke, 2021).

Sound. We defined three types of sound that we needed to reproduce in VR: ambient sounds (e.g., alarms, music), chitchats, and interactions with health professionals. We recorded multiple ambient audios at different locations of the real pathway, such as the sound of the radio in the waiting room, which was usually reported during interviews. We ensured that private patient conversations were not recorded. We created spatialized audio sources and located them precisely in the environment where they had been recorded (req. 5).

Virtual characters. We populated the environment with three types of avatars: those who reproduce professional activity around the patient (req. 6), those who interact with the patient, both verbally and with specific gestures (req. 7), and other patients. We used medical world avatars from a free database¹¹ and animated them when possible. In some cases we had to use motion capture devices to record specific movements, such as taking temperature on the forehead, or placing a catheter.

Interactions. We reproduced various dialogues between health professionals and patients, based on excerpts from the first-person video (req. 7). Patients could then interact in VR with the avatars of health professionals, answering their questions with a simple dialog model (req. 7). Utterances of the health professionals could be both heard (repeated if necessary) and read, as well as answered by pointing at a set of possible written answers. We adapted the interaction for the steps when the user would be lying down. Patients could also interact with different objects by using the controller, notably seats and sofas placed at adequate places within the circuit (req. 3 & req. 8) to allow patients

⁹ <https://unity.com/>

¹⁰ Cinema4D - <https://www.maxon.net/fr/cinema-4d>.

¹¹ RocketBox: <https://www.microsoft.com/en-us/research/blog/microsoft-rocketbox-avatar-library-now-available-for-research-and-academic-use/>.

to sit in VR and experience waiting periods and thoughts associated with them.

Stretcher. We recreated the change of posture and point of view by positioning the patients into a real stretcher without removing the headset. Patients did not leave the stretcher until near the end of the circuit where we performed the inverse manipulation. Using a real stretcher allowed us to change the position of the patient from sitting to lying down, as it happens in reality (req. 9).

Finally, as recommended by Kalantari and Neo (2020) we calibrated the systems through pilot tests with ordinary people. We ended up with two environments: a 10 min tutorial and a 25 min. ambulatory circuit¹² (see Fig. 5). The iterative design process was crucial to test locomotion, calibrate the interactions, design the stretcher operations and ensure the environment was realistic enough.

5.4. Issues with the pathway to focus on

As a last step, we cross-referenced the needs of architects with the data collected during the field study (observations, patient experiences, and remarks of health professionals). We could identify three issues in the real ambulatory pathway that we would try and assess later with our VR environment (RQ2).

- **Loss of spatio-temporal references related to circulations** (Issue 1). Architects design circulations so as to improve the fluidity of the pathway, facilitate the work of the health professionals and facilitate patient orientation and guidance. However, as we could observe, and as professionals remarked, short distances (notably caused by space optimization), bad signage (we saw in Section 4 that signage is often neglected) and stress can provoke the loss of spatio-temporal reference points for the patients.
- **Lack of intimacy and confidentiality in open spaces** (Issue 2). The architects designed the ambulatory pathway as a place of living but also as a “functional” care place. They designed a fully open care space to facilitate communications (care professionals we interviewed confirmed this communication gain) and shorten circulation times. However, observations, as well as interviews with patients and professionals showed that the lack of intimacy in open spaces could be disturbing for patients, notably the constant hearing of everybody’s ongoing conversations in the area.
- **Stress during waiting times despite architects’ efforts** (Issue 3). As we observed, and as patients explained (less so professionals), waiting is not a good experience as it causes a rise of stress, even if architects tried to tackle this problem upstream (using specific colors, materials, volumes, etc.).

These three issues correspond to actual problems patients experience in the ambulatory pathway, and we wanted to evaluate if our VR environment allowed to assess them, by documenting how patients find (or do not find) their bearings, by exploring their sense of intimacy and confidentiality, and their anxiety related to waiting times.

6. Collecting and comparing patients experiences in VR and in reality

Our main research question (RQ1) was: to what extent are the experiences lived by patients in a VR environment (corresponding to what an experience prototype of an ambulatory pathway would be) similar to the real-life experiences of patients in the actual pathway? Our secondary question (RQ2) was related to understanding if the issues described in the real ambulatory path can also be assessed in VR. The key to answering both questions was to collect and compare patient experiences in both conditions.

¹² See complementary material: <https://www.youtube.com/watch?v=BAOmGLkfl3c>

6.1. Experience collection method

Different methods aim at collecting data about human lived experience. As we saw in the related work section, questionnaires are not sufficient to capture all the dimensions of lived experience (Hassenzahl and Tractinsky, 2006; Light et al., 2010). We, therefore, turned to interview methods. Høffding et al. (2022) described nine methods dedicated to the collection of lived experience. From these methods, we selected the micro-phenomenological interview (Vermersch, 1994) as the one we would use because 1) it enables to collect lived experiences of participants at a fine-grained level (Cahour et al., 2016), 2) it does not require traces of the activity such as productions, documents or videos, 3) a precise method exists for analyzing and comparing different experiences (Valenzuela-Moguillansky and Vásquez-Rosati, 2019) (see Section 6.6). Furthermore, it had already been used in HCI to collect lived experience of interactive systems (Françoise et al., 2017; Hogan et al., 2015) and VR environments (Prpa et al., 2018).

The aim of an investigator during a micro-phenomenological interview is to guide the interviewee into both the recall of a past situation and the subsequent verbalization of the corresponding experience (Vermersch, 1994; Cahour et al., 2016). Unlike traditional semi-structured interviews, the interviewer’s role is to help the participant retrieve a precise moment of experience and put them in a state where they can “live again” this experience. In this way, the interviewee can verbalize how the experience unfolded, along different dimensions. The interviewer should refrain from asking “why” questions, as those are prone to trigger analytical judgment on what happened at the time of the action rather than a description of what happened and was experienced (Cahour et al., 2016). Indeed, Vermersch warns against the fact that interviewees tend to rationalize and comment on what they lived (judgments, beliefs, preferences, or theoretical knowledge) instead of describing what they actually did and experienced. He argues that although these analytical dimensions are important to understand what happened, they are not constitutive of the experience itself (Vermersch, 1994; Petitmengin et al., 2019). By focusing on what was lived, the interviewer helps the participant access and describe different dimensions of the experience. For additional insights on micro-phenomenological interviews, readers can turn to (Hogan et al., 2015; Petitmengin et al., 2019; Prpa et al., 2020).

It must be noted that this study introduces a novel method for comparing experiences in VR and reality. By venturing into uncharted territory, we acknowledge that limitations inherent to this new approach may arise. These limitations are discussed in Section 8.

6.2. Participants

Two ophthalmologists surgeons recruited the participants among their patients. There were two groups (Fig. 6).

The participants of the *VR Group* ($N = 8$) (7 females, 1 male; mean age = 70, $SD = 7,73$) experienced the VR environment before the surgery and were interviewed right after. They had no medical conditions contraindicating the use of VR, nor did they suffer from severe vision problems that would make the VR experience impossible or excessively challenging (such as severe glaucoma or age-related macular degeneration).

The participants of the *Reality Group* ($N = 8$) (6 females, 2 males; mean age = 73,5 ; $SD = 5,73$) were interviewed on their experience of the real surgery during the post-operation phase and did not experience the VR environment. They had the same vision problem as those in the VR Group.

All participants had full cognitive and sensorimotor capacities (no Parkinson disease for example), and no medical contraindications for being interviewed (no psychiatric or dementia history, no use of psychoactive medication or substances, etc.). We did not conduct VR tasks nor interviews on the same day as the surgery. Participants were not compensated for their time. All participants agreed to participate in the study and signed a consent form. The protocol was validated by an ethics committee specialized in health protocols.

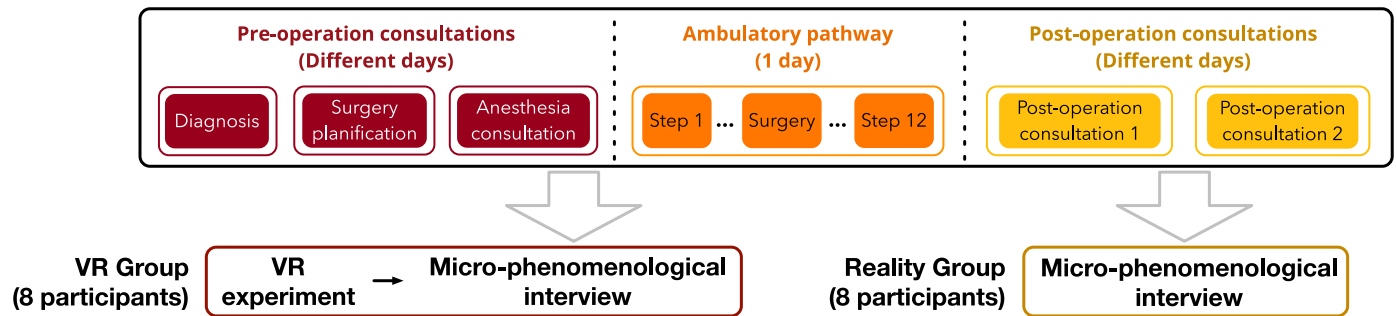


Fig. 6. Participants in the VR Group experienced the VR environment, then had a micro-phenomenological interview. Participants in the Reality Group only had a micro-phenomenological interview.



Fig. 7. After the VR task, participants went through a micro-phenomenological interview. The stretcher used during the VR experimentation is visible in the background.

6.3. Setup and apparatus

VR tasks and interviews were conducted in the same room (Fig. 7). Interviews for the Reality Group were conducted in different rooms of the clinic. The VR environment was run on an HP Omen 15 laptop computer (AMD Ryzen 5600H processor, Nvidia GeForce RTX 3060, 16 GB RAM). Participants in the VRGroup wore an Oculus Quest 2 HMD connected to the laptop with an Oculus Link cable with its controllers. We chose this HMD because it is light, has easy to grasp controllers, and can be used in a small room at the hospital. We had to use an external laptop since the HMD lacked the necessary power to run the VR environment.

6.4. Procedure

Participants in the VR Group started with the VR tutorial to learn the main controls and for us to verify they did not suffer from motion

sickness. They then followed the VR circuit until step 6, where we helped them to the stretcher while keeping the headset on. They continued until step 9, where they left the stretcher and finished the circuit. The full VR session (tutorial + ambulatory circuit) lasted around 35 min. After completion, they filled the Spatial Presence in Immersive Environments (SP-IE) questionnaire (Khenak et al., 2019), then we carried out a micro-phenomenological interview (Vermeresch, 1994) on the experience of the VR ambulatory pathway. Fig. 7 depicts the room where interviews were conducted and the stretcher used during the experiment with the VR Group.

Participants in the Reality Group only went through a micro-phenomenological interview about the ambulatory pathway they experienced a few weeks earlier. Interviews lasted around 45 min.

During the interviews, we specifically targeted episodes of interest that matched with the key experiences of patients, as well as the issues with the pathway we had identified (Section 5.4). The first targeted episode lasts from the moment the patient is installed in the

stretcher (step 5 of Fig. 4) to the anesthesia room (step 7). It includes interactions with health professionals (preoperative procedures such as placing a catheter or electrodes), waiting periods, open-spaces, changes of posture (sitting to lying position), non-autonomous circulations, etc. The second episode lasts from the post-operation monitoring (step 9) to the snack room (step 12). It includes waiting periods, interactions with professionals, and autonomous circulations. After a few interviews, we added a third episode of interest, which patients were likely to elicit. This third episode lasts from the entrance of the service (step 1) to the end of the first check with a nurse (end of step 3). It includes autonomous circulations, dialogues with professionals, and waiting times. In total, these three episodes cover 10 steps of the ambulatory journey.

6.5. Data collection

We recorded the video and audio of each micro-phenomenological interview. We also collected VR traces (trajectory and events) and a first-person video (what is seen in the VR headset by the patient) for the VR Group. We assigned each participant a unique ID and anonymized all interviews. In what follows, we refer to the participants by their group name (VR or Reality) and a number, e.g., R5 corresponds to participant 5 in the Reality Group.

6.6. Data analysis

We chose to analyze our interviews with the procedure proposed by Valenzuela-Moguillansky and Vásquez-Rosati (2019). This method aims to describe experiences collected in the interviews with diachronic and synchronic structure, and later to compare and abstract those structures. We chose it for three reasons: it ensures that the diachronic and the synchronic richness of the experience collected during the interview is not lost, it enables comparison between participants' experiences, and it documents the criteria used for building structured descriptions of experiences.

This analysis method includes 5 steps:

Data preparation: transcription of each interview. We transcribed the recordings, also using the video to describe gestures or gazes of the participants. Then, we discarded what cannot be considered as a description of authentic experience, only keeping *descriptems*, i.e., excerpts of the transcription that are deemed to correspond to authentic experience (Petitmengin et al., 2009). For this, we used what was said (e.g., present tense is a cue of authenticity), the questions of the interviewer (e.g., ensuring they were not inducing any answers), and the gestures/eye-directions (e.g., describing action with the hands is a cue of authenticity, as is looking up and sideways while being in contact with the past).

Specific diachronic analysis: understand the temporal evolution of the described experience. We constructed a temporal structure of each participant's full experience by 1) grouping together the descriptems that relate to the same moment, 2) giving a name to the moment, and 3) inserting it in a chronological sequence in relation to other moments. The first-person video was used to help build the structure of the experience for the VR Group. The resulting structure constitutes the *diachronic* structure of the experience.

Specific synchronic analysis: characterize the structure of the experiences. We further described each moment with *synchronic* categories, according to what the participant lived during this moment. This constituted the synchronic structure of the experience. For example, a participant reported feeling stressed at the beginning of the pathway. This stress was characterized by a weight on the chest. We created a moment named *At the ticket terminal* with two *descriptems* related to that moment. Then, we added the synchronic category: *Anxiety* and its *body-localization* property: *On the chest*, as well as the descriptems justifying such modeling (Fig. 8).

Generic diachronic analysis: compare participants' diachronic structures. We created upper moments to align moments of experiences between participants to allow further comparison. For example, if R1 described a catheter placement in the stretcher and R3 described how a professional placed a blood pressure cuff, they are not talking about the same moments. Yet, these two moments belong to the same step of the ambulatory pathway, where the blood pressure cuff and the catheter are placed when the patient is on the stretcher. We created an upper moment "6. Sitting in the stretcher" containing a sub-moment "6.1 Surgery preparation #1", and placed R1 and R3's experiences into this moment. With this procedure, we defined and normalized 14 upper moments (column 1 of Table A.3) and 9 sub-moments (column 2 of Table A.3). Interestingly, these moments do not entirely match the 12 steps we found in the field study (Fig. 4). This is because what patients reported doing and experiencing do not necessarily correspond to what we observed.

Generic synchronic analysis: compare participants' synchronic structures. All the researchers normalized the names of the synchronic categories we used for each group (in the VR Group, for example, we coded an experience of "Anxiety" and another one of "Worry" in the Reality Group. We normalized both to "Anxiety"). We ended up with 45 and 51 synchronic categories, for VR and Reality Group respectively, which we classified into broad dimensions of experience (see 7.2.1).

The analysis was conducted by one researcher while each of the validation and normalization sessions implicated the three authors. We used the descriptems of the moments or synchronic categories every time it was necessary to check the validity of a decision, getting back to the transcriptions of the interviews when needed. The analysis was carried out using the tool μ PMT,¹³ which helped us manage the interviews, highlight descriptems, organize sequences of moments, and manage a list of synchronic categories that we instantiated within diachronic moments. A summary table of our modeling can be found in the Appendix, Table A.3.

7. Results

We first present the scores on presence (7.1), before answering our main research question on comparing patient experiences in VR and reality (7.2), and our second question on issues (7.3).

7.1. Presence in the VR environment

The answers of the SP-IE questionnaire (for the VR Group) showed that 8/8 participants attributed realness to our environment. They felt a high sense of spatial presence, a high possibility of actions, allocated a high attention to the task, and enjoyed the VR experience. Three participants reported cybersickness verbally during the tutorial or in the questionnaire after the main task. However, none of the participants stopped the VR environment due to severe cybersickness. Finally, 7/8 participants (VR5 did not answer the two questions dealing with presence of avatars) perceived the social presence of the avatars. Fig. 9 shows the results for all participants, with the values for each sub-scale normalized on a scale of 100. The detailed results are presented in the appendix, Table A.4.

All this suggests that, overall, patients felt a strong sense of presence, were immersed in the ambulatory circuit, and felt social presence. It also supports the idea that experiences lived in the VR-ambulatory journey can effectively be compared to those in reality.

¹³ Micro-Phenomenology Modelling Tool <https://yprie.github.io/uPMT/>, a brief description of this tool is available in (Rivière et al., 2024).

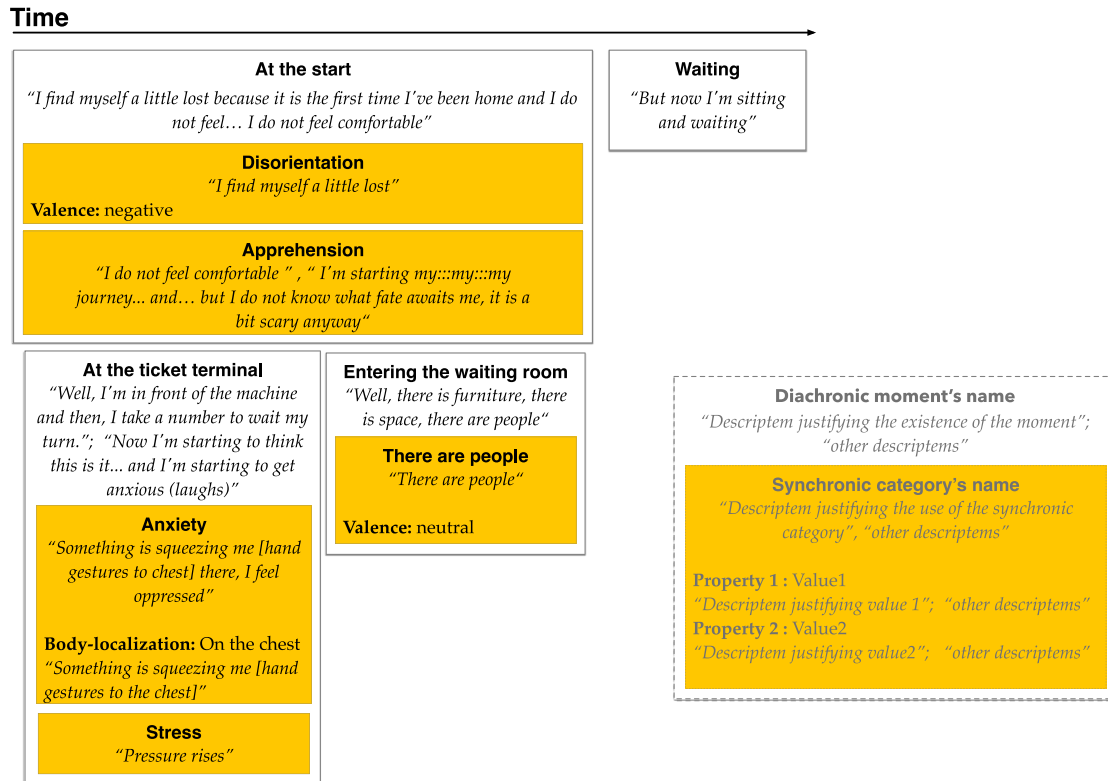


Fig. 8. Example of the specific analysis of the experience of VR1 as described in the transcription of the micro-phenomenological interview. Descriptems from the interviews are classified into diachronic moments and sub-moments (white boxes), which are organized sequentially and hierarchically (diachronic analysis). Afterwards, moments are further described with synchronic categories represented in yellow, also justified by descriptems (synchronic analysis). Later, during the normalization and generic analysis of the descriptions, the names of some moments were standardized (e.g., "At the Ticket Terminal" became "1.1 Ticket Terminal" and "Waiting" became "Waiting #1"). Additionally, some categories were rephrased (e.g., "There are people" became "Perception of other patients").

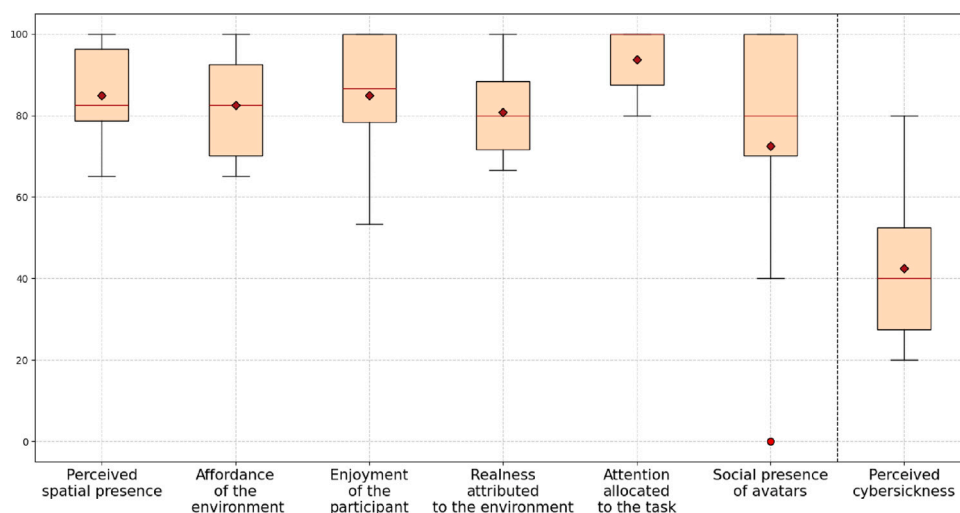


Fig. 9. Results of the SP-IE questionnaire (for the VR Group).

7.2. RQ1: comparison between experiences in VR and reality

We first broadly present the dimensions of lived experience we found and how they are distributed within both groups, before focusing on the main similarities and differences.

7.2.1. Dimensions of lived experience in both groups

From the first three steps of analysis, we got 16 (one per participant) diachronic sequences, each encompassing different moments of experience, and identified 96 distinct synchronic categories. We classified the synchronic categories into 4 broad dimensions of experience (see [Table 1](#)):

The **thought** dimension describes cognitive thinking in diverse forms such as self-addressing (self-motivation, telling to myself that I am lost), desires, rationalizing what is happening, etc. A good example is given by R5, who felt lost during the real tour, which provoked an inner speech: “I say to myself, I am lost, where am I going? I say to myself, I think it must be this way. I can see more or less... I go there [gestures] and suddenly I hear nurses and I ask them [...] I find myself in the hall, in the waiting room. I say to myself, there is a problem (laughs), because I have to pay, I know that”.

The **emotion** dimension includes all the emotions that participants felt. For example, VR1 explains feeling anxiety just before the surgery: “I think: this is it... and then I start to feel anxious [laughs]. Something is squeezing me [hand gestures on chest], something is going to squeeze me, I feel oppressed”.

The **sensation** dimension is a high-level construct, which refers to sensations felt by participants. For example, VR2 describes a sense of normality in the pathway and its impact: “At this moment, I know I am going to be taken care of [...] I let myself go, [...] I wait for it to happen.”

The **perception** dimension has two subdimensions: *social perception* refers to the perception of other persons, who can be patients or health professionals, while *sensory perception* refers to the direct perception of sensory clues. For example, VR7 described the sound (direct perception) of other people around (social perception): “The space is extremely noisy, you can hear the noises of the nurses, telling their little stories”.

[Table 1](#) shows all synchronic categories, with those in bold indicating similarities between both groups. Among the most used ones, 27 are present in both VR and Reality groups. There were more occurrences of the synchronic categories for the Reality Group (321) than for the VR Group (213), which cannot be attributed to variations in interview duration. [Table 2](#) presents synchronic categories that appear at least twice within a group.

Overall, if we compare VR and Reality Group over the number of users reporting about the dimensions, we can say that: except for VR2 and VR7, who did not describe emotions, all the participants described experiences belonging to all the dimensions (see [Table A.3](#)); there is coherence within the two groups on the most described moments (normalized moments 6, 7, 8, and 11), and there seems to be more participants of the Reality Group reporting for these last two moments.

Many comments can be made about this rich data, but we will focus on the most important findings in relation to our main question: what can we say about the similarities and differences between the reported VR and real-world experiences?

7.2.2. Similarities between experiences

Perception of sound is similar in both groups. The first similarity was uncovered through the accounts of twelve participants who reported hearing discussions and noises during the circuit (17 occurrences for both Reality and VR Group). Participants reported hearing professionals’ voices (VR1,5,6,7 - R5,7,8), hearing chatter (R4,8 - VR5,6,7), hearing the preparation of other patients (R5,3,7), and overhearing other conversations (R4,5,8 - VR1,3,4,6,7). In both groups, participants perceived sound differently. For example, R4 explained being annoyed by the noise: “I started to listen to others, I was a little bit, shocked, I mean shocked. [...], [by] the lack of reserve, of discretion. They spoke very very

loudly”. Yet, some participants, such as VR4, felt that it was a normal part of the service, which was reassuring: “I hear everything, [...] it is reassuring to see that there are people”. The sound may be more vivid when on the stretcher and in the anesthesia room, but overall, sounds are perceived everywhere in the circuit.

Both groups perceived health professionals around them. All the participants reported having a strong perception of health professionals (28 occurrences for the VR Group and 31 occurrences for the Reality Group) throughout the circuit. VR6 gives an example of such perception: “I see nurses in front of me, like when I went to the stretcher. I see them”. We found that perception of professionals is usually accompanied by a positive feeling in both groups, as explained by VR1 “I get much attention, so... I do not have time to think much. [...] It feels less lonely already”. Participants in reality shared similar perceptions, as R8 explains: “Then there is a nurse who came to get me and reclined the chair into a lying position”.

Participants in both groups felt that they were being taken care of. This sensation was categorized 14 times in the VR Group and 17 times in the Reality Group. R1 explains it in these words: “The different people do not stop taking care of us, to check if everything is OK, to take the blood pressure, to put the catheter [hand gestures], to check if everything is fine”. Such experience occurs when participants follow a health professional, are transported, or when receiving medical care: in the VR Group, VR1,2,8 reported it when they sat in the stretcher, VR8 during the post-anesthesia monitoring, VR3,4,5 when the chair was laid down and moved to the anesthesia room: “They are pushing me. I let myself be guided. Well, I have no choice but to lie down on the stretcher that pushes me” (VR4). In the Reality Group, this sensation appears earlier in the circuit (in the nurses’ box for R1,2,3), but similarly to the VR Group, participants largely reported experiencing it when positioned in the stretcher (R1,2,3,4,6,7), moved (R1,4,5), and laid down (R4,5).

Installation in the stretcher was accompanied by a loss of agency in both groups. Nine participants reported a loss of agency (6 occurrences in Reality and 11 in VR) appearing mostly when sitting in the stretcher or during the transition to the anesthesia room (R3,4,5,6 - VR4,5,7), as VR4 explains: “From the moment they put us in the chair they carry us around. [unhooked eyes, expressive hands]. You just have to let them”. This loss of agency is not lived negatively for most of the participants, as VR7 explains: “I can’t turn back. But that’s basically because the professionals are taking care of me”.

Participants in both groups had the experience of a service in normal operation. Six participants (VR2,5,7–8 occurrences, R2,4,6–7 occurrences) explained feeling a sense of normality, which calmed them down. In both groups, such a sense of normality was triggered mainly by health professionals doing their work. R4 explains: “I saw two people who came to wash their hands for a long time [eyes up] for a long time and in fact they were both talking, but I never heard. I found that normal, very good, very good”. In a similar fashion, VR2 explains: “It is done normally. This is what I expect. People do their work, they come, give me things to do...” (VR2). R2 also described that the sense of normality is coming by seeing the back and forth of other patients transported by health professionals: “Nurses were passing by, going in one direction. And it is kind... nobody looks surprised. Everything looks like it is normal” (R2).

Participants in both groups experienced anxiety and stress. Four participants in the VR Group reported apprehension (VR1,3,4,6–7 occurrences) and even rather strong stress (VR1,6–3 occurrences): “I begin to think that this is it and I begin to feel anxious (laughs). [...] Something is squeezing me [gestures hand on chest] there, something that squeezes me, I feel oppressed” (VR1). Similarly, four participants in the Reality Group reported experiencing apprehension (R1,2,3,5,7–6 occurrences) - and

Table 1

VR and Reality groups' synchronic categories organized by dimensions. Categories shared between groups are highlighted in bold.

	VR Group	Reality Group
Thought	acceptance, assumption, desire , haste, judgment , memories, perception of time , projection, questioning, the surgery is coming , the surgery is over	desire , internal focus, I am lost, judgment , lack of information, perception of time , ready, regret, self-motivation, supposition, the surgery is coming , the surgery is over , think about family, we are going now
Emotion	annoyance, anxiety , apprehension , relief , serenity, surprise	anxiety , apprehension , excitement, fear, hope, joy, relief , shock, surprise
Sensation	awkwardness, being taken care of , care, comfort , concentration, confidence , difficulty in VR, discomfort, disorientation , loneliness, loss of agency , no more need of VR controllers, normality , oppression, reassured, relaxation , strangeness , strangeness in VR, stress , trust, unknown, well-being	animation, astonishment, being taken care of , calm, comfort , confidence , disorientation , fatigue, hunger, impatience, letting go, loss of agency , normality , pain, reassurance, relaxation , strangeness , stress , well-being
Sensory perception	body perception , perception of signage, perception of space , perception of sound	body perception , perception of light, movement perception, perception of an object, perception of space , perception of sound , reduced perception
Social perception	perception of health professionals , perception of other patients	perception of the cleaner, perception of health professionals , perception of other patients

stress (R2,5,6–4 occurrences), as reported by R6: “I was really, a little stressed, but they [the nurses] reassured me, and I really enjoyed it”. In both groups, those emotions appeared from the beginning to the end of the circuit. It generally disappeared after the operation, and is generally replaced by a sensation of relief, even in VR (R1,2,6,7 - VR1,3,6).

7.2.3. Differences between experiences

We found many synchronic categories of experience in one group that did not exist in the other. Although most of them are idiosyncratic categories (e.g., we found only one occurrence of *Shock* in the VR Group and none in the Reality Group), some categories appear many times in one group and none or few in the other.

Participants in VR did not really perceive other patients. All the participants reported perceiving other patients around: “I see a man I think and a lady, I was rather surprised to see that there were other people, we are not in the room, alone” (VR4). However, this social perception seems more pronounced in the Reality Group, as shown by the number of occurrences (16 vs 5). In VR, the participants reported feeling the other patients in the waiting room but not after, while in the Reality Group, other patients were perceived all along the circuit, as reported by R3 in the snack room: “there are other patients waiting too. Well, not much is said, nothing is said... Nobody talks”.

Perception of time seems more important in reality. Although participants in both groups explained that they had a perception of time passing, we found 27 occurrences of this category in the Reality Group and only 12 for the VR Group. This may suggest that perception of time is more pronounced in reality than in VR. In particular, participants in the Reality Group explained that they experienced quite long waiting times: “And here, it lasted hours. It was very long” (R4). On the contrary, in VR, participants reported faster waiting phases, as explained by VR2: “I thought it was pretty fast. It went by quickly”. Perception of time seems even more prominent in reality as watches and phones are left in the

locker room. Some participants are trying to keep track of time and measure it in their head, as R3 explains: “I wait for him to come and get me. It was also long, very long. Well, I see the door opening. That is why I saw that I waited so long because I always saw the stretcher bearer coming out”. Overall, the perception of time in virtual reality appears to differ from that in reality and warrants further investigation.

Some VR participants report VR-related experiences. Two VR-related synchronic categories are inherent to the VR environment and the controllers: “difficulties in VR” (7 occurrences), and “Strangeness of VR” (4 occurrences). Four participants (VR1,2,3,4) described difficulties using the joysticks and moving in the environment. This appears to be related to the sense of disorientation that participants reported in the VR Group. VR1 and VR2 also reported VR-related strangeness. VR2 reported touching things in reality that was not in the headset: “When I sit in the seat, it is not really like a regular seat. It is strange because it is a real seat, but at the same time I am not in the right place, I am bumping into it with my legs...”. VR1 also described feeling strange being operated on the stretcher and not on an operating table.

Reduced perception-related experiences only appear in reality. The category “reduced perception” (24 occurrences) is related to a loss of direct perception (vision and sound) and was found only in reality. For example, R1 explained losing sight due to anesthesia, and R5 could no longer hear because the hearing aids were left in the dressing room. In the VR Group, although some patients explained that they could no longer see because they were lying down (similar to reality), none described any other type of loss of perception.

Bodily perception-related experiences are different. All participants of the Reality Group reported having “body perception” (17 occurrences), versus 4 participants in the VR Group (VR1,2,4,6–4 occurrences). These perceptions are not of the same type. For the Reality Group body perceptions came mostly from care interventions, such as the feeling of the blood pressure cuff inflating (R1), or the feeling of being anesthetized

Table 2

All the synchronic categories for each group reported by at least 2 participants in each group, along with their number of occurrences. The categories are ranked according to the number of occurrences, followed by the number of participants who reported each category. Categories shared between groups are highlighted in bold.

VR Group	1	2	3	4	5	6	7	8	Reality Group	1	2	3	4	5	6	7	8
perception of health professionals	3	1	3	4	4	9	2	2	perception of health professionals	5	2	4	2	3	6	4	5
perception of sound	2		1	2	4	5	3		perception of time	2	2	9	7	1	1	3	2
being taken care of	2	1	1	5	1			4	body perception	1	3	3	1	3	1	3	2
perception of time		2	2	1	1		4	2	being taken care of	3	3	5	1	3	1	1	
loss of agency		1		2	2		3	3	reduced perception	4		4	3	4		6	3
disorientation	4			1	2	1	1		perception of sound			1	4	6	1	1	4
apprehension	1		1	2		2		1	perception of other patients	1	3	5		5	1	1	
desire	1		1		1	1		1	perception of the space	1		4	1	1		2	1
difficulty in VR	1	5		1					disorientation		1	1		2		2	1
body perception	1	1		1		1			relaxation	2	1		2	1			1
reassured					3		1	2	strangeness		1	2	1	1	1	1	
haste					1		1	4	apprehension	1	1	1		2		1	
perception of other patients	2			1	2				the surgery is over	1		1		1	1		1
normality		5			2		1		anxiety	5			1		1	4	
judgment		1	3				2		loss of agency			2	2	1	1		
perception of the space		2				1	1		relief	2	1				2	2	
well-being	1	2						1	the surgery is coming			1		3		1	1
relief	2		4			1			letting go		2	1		1	2		
questioning		1						1	well-being	2		2	1		1		
strangeness in VR	1	3							hope			1				2	1
anxiety	2							1	normality		2		4		1		
operation is over			2			1			stress		1			1	2		
stress	1					2			we are going now		1			2	1		
acceptance			1	1					desire		1		1	1			
concentration					1			1	I am ready			1		1	1		
surprise					1	1			trust						2	2	
memories			1	1					perception of the cleaner		1			2			
									thoughts for the family					1			1
									annoyance		1				1		
									calm					1	1		
									impatience			2					1
									joy			1	1				
									judgment	1	1						

(R2): “I feel like I am in the glue. A bit floating.. And I do not feel like moving, I do not feel like... anything... I am all squishy [laughs]. I am lying down, I am... honestly, I am cushioned in this case”. For the VR Group, body perceptions were related to stress (VR1,4), thirst (VR6), or triggered by touching something in reality when it was not present in VR (VR2).

7.3. RQ2: Assessment of the real pathway issues in VR

We can now focus on our second research question: Can the issues of a real ambulatory pathway be assessed in VR? In Section 5.4, we identified three issues that emerged from our field studies of the real ambulatory pathway. We will now examine whether these three issues can also be identified in a VR environment.

Loss of spatio-temporal references related to circulations. Previously, we had found that in the real ambulatory pathway, patients often felt disoriented and lacked spatio-temporal reference points. In VR, we also found that patient felt disoriented (9 occurrences), especially when being laid down. VR1 explains: “I feel disoriented, I do not know where I am, because I am not sitting. I do not see where I am going, [...] I can only see the ceiling [...] we do not know in which direction we are [speaks with hands] if we are behind the door if we are in the front of the door. It does not make me feel safe...”. Similarly, VR7 described the same feelings of disorientation when transferred to the operating room: “I think it was [gestures] vague. You look to see where you are. [...] Immediately, I try to

see where I'm going”. Moreover, R5 explained getting lost while going to the snack room: “And then I say to myself, I am lost, where do I go now?”. Specifically, at this location, we also observed from the traces at least two VR participants who got disoriented on their way to the snack room.

This suggests that we were partly able to replicate the disorientation experienced by patients on the stretcher.

Lack of intimacy and confidentiality in open spaces. We had also found that the lack of privacy during medical preparation in open spaces could be disturbing for patients, particularly due to the sounds of other patients and health professionals. In VR, participants reported perceiving health professionals and hearing dialogues or conversations of other patients. Some perceived this sounds with a negative valence, as described by VR1: “I hear people talking all the time like this [hand gesture around ear], some people are laughing, there is a bit of heckling and I think it is a bit noisy for me, people are passing by, I hear much noise”. R4 had a similar comment: “but it was the lack of discretion, they spoke very very loudly”. With regard to intimacy, VR5 explained hearing conversations, but did not report it as a problem: “I hear them talk, it is a lot of talk, and it is like their little stories. They are relaxed”. There was no negative valence associated with the perception of the other patients.

This shows that intimacy and confidentiality can be replicated in VR and it was mainly triggered, in our case, by the perception of sound and not by the visual perception of other patients.

Stress during waiting times (despite architects' efforts). Our field study showed that waiting significantly increases stress levels, making the experience particularly unpleasant for patients. We found negative synchronic categories in VR, such as apprehension, stress, and anxiety. However, these categories did not specifically occur during waiting times. Waiting in VR did not last very long and was much shorter than in reality. In the Reality Group, we found waiting time associated with a negative valence (10 occurrences out of 27). R2 explained that waiting times are perceived as long: “*I could not see the clock very well and the time seemed long. [...] it was [...] before the anesthesiologist*”. We also did not find that waiting times are related to increased stress in reality.

8. Discussion

In this section, we discuss our results, the limitations of our study and method, and the potential use of VR prototypes for UCD in architecture.

8.1. Research questions and results

8.1.1. Main research question

Our main research question (RQ1) aimed to examine the extent to which the experiences of patients in VR match those in reality. Our general conclusion is that there were numerous similarities between the experiences lived in the VR ambulatory pathway and the real ones. Nearly all participants of both groups reported experiences that corresponded to our global experiential dimensions (though, sensation, emotion, direct and social perception), and many synchronous categories matched between both groups. These experiences were collected from interviews conducted on the same steps of the pathway, with the same objectives, they appeared mostly during the same period, before and after the operation, when participants were on the stretcher. This indicates that VR allows patients to live experiences that can be deemed globally similar to those lived in reality.

Despite these positive results, there are differences between experiences, some of which can be explained by the experimental context (patients were in VR and not in reality, the locomotion technique was limited, there was no real operation, etc.), other by some limitations in our VR environment that the data analysis revealed. For instance, participants in the VR Group scarcely reported social perceptions of other patients. In particular, they did not see the preparation of other patients, although it turned out to be a part of the experience of the Reality Group. During the design of the VR environment, we focused on ambient sounds and did not specifically record and simulate other patients. Also, although there were patients in our VR pathway, their number was limited, they did not move like health professionals and were not placed next to the user's seat. Another example is that, contrary to what is reported in (Igarzábal et al., 2021), we did not find the same perceptions of time in VR and in reality. This is probably because our waiting times were much shorter in VR than in real life, leaving less time to feel the service workflow and be left with one's thoughts.

8.1.2. Secondary research question

With regards to RQ2 —can the issues of a real ambulatory pathway be assessed in VR?—, the results are mostly positive: confidentiality and intimacy problems could be found in VR, as well as the loss of spatio-temporal references in the stretcher.

However, the lack of intimacy and confidentiality, and more generally, the social perception of other patients, were only due to ambient sound recording, probably because we did not insist sufficiently on patients' avatars. For free movement, it is also not clear whether VR participants felt disoriented because of the controllers or because of

architectural issues. Lastly, concerning the stress related to waiting periods, there was no real occurrence of this issue in VR, nor in reality, which does not support what we found in the field study. This may indicate that this issue needs further confirmation, for example, by using specific stress-related questionnaires.

As participants in the VR Group did not really perceive other patients, it seems that failing to explicitly identify and propose a specific type of experience in VR may result in the absence of that experience for VR users. However, the lack of intimacy was still present, induced by the environmental sounds. We conclude that this may pose challenges for designers, as it is difficult to know in advance which elements will be crucial for studying a particular issue. Conducting ethnographic studies before designing VR prototypes seems therefore crucial for understanding the factors that trigger certain experiences. However, further research is needed to determine the most effective methods for doing so.

8.2. Method

8.2.1. VR environment

Overall, our VR design was successful, and the environment did well in simulating the real ambulatory pathway. Patients were able to go through all the journey, they experienced an operational service and the feeling of being taken care of was described by many, along with a sense of normality. The audios we had recorded in the real ambulatory pathway played an important role in these dimensions, as well as avatars, simulating health professionals despite their low quality. This confirms the findings by Drettakis et al. (2007) about the fact that recorded spatialized 3D sound and social presence increase immersion. Using a stretcher to lie down participants and transport them virtually played a key role, as evidenced by the many reports on loss of agency. Achieving this degree of realism was possible thanks to the field studies we carried out beforehand. In particular, the first-person video we shot on the pathway guided many of the design choices. Using such types of videos together with BIM 3D models from architects is a great tool for simulating real environments. Notably, it helps apprehend the building as a set of rooms, walls, and corridors and as a place for dialogues and social life.

It should also be noted that the participants presented an advanced age (mean of 70 years old in the VR Group and 73,5 in the Reality Group). This is typical for the population undergoing ophthalmological surgery. We were concerned that patients may report ocular difficulties in the headset, but none of them described such a sensation. Also, while we initially feared that age might pose a challenge for using VR, most participants navigated the VR environment without significant difficulties. However, certain synchronic categories might have emerged more prominently within this population, such as reduced perception due to poor eyesight or hearing problems.

Limitations. Some difficulties may have affected the results, particularly the locomotion technique we selected. Although it worked, using a controller was complicated for elderly patients, and required concentration from them (in one case, assistance was needed). Further work is clearly required on locomotion techniques for VR architectural prototypes, which should be close enough to the real experience of walking in a building to allow users to experience the space, while remaining comfortable. Future studies could consider more embodied locomotion techniques, such as walking in place (which would allow to extend the field of view), or leaning-based paradigms (Zielasko and Riecke, 2021), which may be easier for elderly persons to appropriate.

8.2.2. The micro-phenomenological approach

We wanted to move beyond questionnaires so as to systematically assess and compare lived experiences. For this, we used micro-phenomenological interviews and diachronic/synchronic experience modeling from the resulting transcriptions (Valenzuela-Moguillansky and Vásquez-Rosati, 2019).

Concerning the data collection, we showed that it is possible to conduct micro-phenomenological interviews about virtual reality experiences with elderly people. With regard to data analysis, we could model the description of experiences with numerous diachronic moments and synchronic categories. We used a bottom-up approach to avoid premature categorization of experiences, and we unfolded four broad experiential dimensions. Some of them correspond to those proposed by Brakus et al. (2009): *Thought* is part of the larger *Intellectual* dimension, *Emotion* relates to the affective dimension, *Social* and *Direct perception* to the social and sensory dimensions. However, the *Sensation* dimension is trickier, as it corresponds to a high-level feeling, which could belong to either the intellectual or the emotional dimension.

Although by definition lived experience is idiosyncratic, normalizing synchronic categories allowed us to compare the lived experiences of different participants. Because specific moments were kept, as well as descriptives, our synchronic and diachronic models do not “hide” the experience of each person but rather provide a common layer to organize what is experienced and when. Similarly, Valenzuela-Moguillansky and Vásquez-Rosati (2019) underline that it is possible to find matching diachronic moments of experience between participants, however, there is no mention of being able to produce diachronic moments that match moments reported by all the participants, as we did. We suggest that we were able to do so because we were within a well-defined and known sequence of steps.

Our diachronic and synchronic data analysis, though not new, was conducted with a dedicated tool and with a systematic approach to normalization that proved useful. What is new is that we applied the micro-phenomenological approach in an experimental setting where the experiences of two groups of participants were modeled and compared. We are confident that this is the first study of its kind to compare precise descriptions of experiences between reality and VR, in an open environment. Such an approach was necessary to answer our research questions, but it also permitted us to assess a new method that can now be used beyond our context. This can be done for comparing the experiences of different groups of participants in their full richness and in a temporally structured way, moving away from the predefined themes of usual questionnaires by exploring emerging aspects of lived experiences (such as our lack of confidentiality in open spaces). The method can also be used in exploratory studies, as it adds more generalizability and robustness to the analysis process, as the different models (diachronic and synchronic) can be shared. However, the method necessitates some adjustments and the establishment of a framework, that can only be obtained through replication and further developments and formalization.

Limitations. Our results are based on empirical data obtained from interviews with two groups of eight patients each. One limitation of this study is the low number of participants, which is due to the inherent difficulty related to such a complex medical environment, and the strict inclusion criteria set by physicians, all the more so with elderly patients. Even though some categories of analysis are stable throughout most of the participants' interviews, we did not reach data saturation, because new more idiosyncratic categories kept appearing with new participants. Further work is therefore needed to assess what saturation would mean in our context and how it could be attained.

Another limitation may concern the time elapsed between the surgery and the micro-phenomenological interviews in the Reality Group compared to the time between the simulations and the interviews in the VR Group. Interviews for the Reality Group typically

occurred during post-operative consultations (see Fig. 6), held 1–4 weeks after surgery. This may not be a problem because micro-phenomenological interviews have been shown to be robust to such delays, particularly for recalling extraordinary experiences (Evrard et al., 2018), such as surgical operations. Additionally, we found more occurrences of synchronic categories in the Reality Group than in the VR Group, suggesting that the delay between the surgery and the interview had a limited impact.

Despite these limitations, given the richness of the data, we are quite confident that the results presented are robust, as shown by the number of occurrences of the general synchronic categories and their similarities.

8.3. Towards the use of VR prototypes in architecture

Our general approach in this research was to assess the kind of experiences a high-fidelity architectural VR experience prototype could induce in patients, compared to what a real building and process actually induce. For this, we needed to build a VR environment that played the role of a prototype architects could have built at design time, and test to what extent the experiences of patients within it and in reality were similar. Our VR environment is not, strictly speaking, a prototype as it is not a representation of a design idea. Nevertheless, it showed that 1) it is possible to create such prototypes, and 2) the experiences within them are comparable to those in reality. In this sense, it played its role. Getting back to our initial interest in UCD for architects, several points remain to be discussed.

Can architects build VR prototypes such as ours during the design phase? We tend to answer positively because architects use 3D models of buildings early on, design ambulatory pathways upstream, and because professional practices are classical and can be simulated. However, such an approach would probably need to take some time to iterate with health professionals. Of course, the definitive answer can only be determined in the field with architects building real prototypes in real projects.

Generalizability to other situations. Can our conclusions on similarities of experiences be generalized to other types of buildings, organizations, and activities? It seems to us that the answer is positive because buildings are not just abstract architectural spaces but spaces where users' tasks and activities occur. If we consider patients as specific users who have specific tasks to accomplish and if we can build a VR environment that allows them to carry out those tasks and have experiences comparable to reality, then it should be possible to use VR prototypes to design almost any type of building and activity.

Designing VR prototypes to study various experiences. We believe that VR environments can be used to simulate almost any kind of experience architects are interested in. This ranges from general human experiences related to things we all do in buildings (walking down corridors, perceiving light or sound) to activity-specific ones (being oriented at the entrance of a hospital as a patient or a visitor, losing agency by being laid down on a stretcher in an ambulatory ophthalmology pathway). Attaining the targeted experiences depends on the fidelity of the prototype one wants to achieve and the effort needed to collect the “important” experiences one wants to explore, and to design and implement the environment. One has notably to balance the degree of fidelity of the environment with the duration of the proposed experience with regard to the questions it helps to answer. For instance, it is clear that even though we tried to simulate as much of the real building as possible, certain aspects escaped us or collided with the design of the study. Waiting times were indeed too short in VR, but longer times would have made the experiment too long, especially for the elderly. There are also interesting questions related to designing VR prototypes that are realistic enough to feel “higher-level” experiences. For instance, by analyzing the similarities in experiences

using synchronic categories, we found that participants were able to describe both low-level perceptual feelings and sensations (easy to design), as well as higher-level categories such as the feeling of being taken care of or a sense of normality (more difficult to design). The whole point of VR simulation may be to reach such experiences so as to leverage them, yet as they cannot be directly related to specific features of the environment, achieving this can be challenging.

Economic principles of VR prototyping. If prototypes are built and evaluated too late in the architectural workflow, architects or business stakeholders may not welcome changes anymore. Yet, if it is too early, the plan of the building and the description of the processes taking place within it may not be described at a sufficiently precise level to allow to build a prototype with sufficient fidelity to collect actionable data. Architects interested in creating VR prototypes need to consider what [Lim et al. \(2008\)](#) call the economic principle of prototyping, defined as follows: “the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable”. We created a complete ambulatory pathway because we were in an exploratory study, but architects could simply reproduce a part of the building related to their questions. For example, if privacy in open spaces is the question to be answered, it is acceptable to design just one open space and study patients’ lived experiences in it. Also, the method(s) that should be used to collect experience will depend on the number of participants and the questions that need answering. If one is interested in assessing if a precise experience arises or not, then questionnaires can be the best solution. If the objective is to explore experiences and usages, then first-person methods seem more appropriate, be it classical semi-structured interviews or micro-phenomenological interviews, if more precision is needed.

Cost-effectiveness of VR prototypes. Having access to the real ambulatory pathway allowed us to replicate it in a high-fidelity VR prototype. However, building a VR prototype for UCD from early blueprints can be both costly and methodologically challenging. Yet some activities and experiences can be shared between contexts and projects (e.g., human experiences in buildings, patient experiences in health facilities). We believe that models that describe what types of experiences can be lived, how to trigger them, and how to verify across various contexts should be made available for reuse. It is also possible to reduce deployment time for interactive virtual characters by using (open-sourced) libraries of reusable avatars, animations, interactions, (AI-)dialogue models, etc. An alternative approach to simulating complex interactions and activities could be to use social VR for the users to interact with avatars that actors could play.

9. Conclusion

This work aimed to study whether VR prototypes could be of use for architects at design time to collect the experiences of patients that they could take into account to iterate on their design. We designed and built a VR environment that could play the role of such a prototype, allowing us to compare patients’ experiences in VR and in reality. For this, we replicated an ambulatory pathway in VR and compared the experiences of real patients in VR and in reality using a micro-phenomenological approach for experience collection and modeling. This study is the first of its kind to compare precise descriptions of experiences of a building and the associated services and not just scores associated with questionnaires. The results show that our prototype allowed users to carry out activities in the building and that their experiences are comparable to those in reality. We found that low-level perception is attainable, such as perception of sound, human presence, stress, etc. More interestingly, “higher level” experiences are also attainable, such

as the perception of being taken care of, or the loss of agency. All this suggests that VR prototypes can help architects collect user experiences during the design phase and thus have a more user-centered approach (in our case, even a patient-centered one) to designing many aspects of future buildings. However, this evolution will depend on cost-effective methods to create such prototypes from early blueprints of architects.

CRedit authorship contribution statement

Jean-Philippe Rivière: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing, Formal analysis. **Louis Vinet:** Investigation, Methodology, Writing – original draft, Writing – review & editing, Formal analysis. **Yannick Prié:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

We thank Marine Czaplinski and Brice Conraux for their efforts in developing the virtual environment. We also thank the Jules Verne Clinic and the Institut Ophtalmologique de l’Ouest, particularly Anne Barrucand, Dr. Frank Becquet, Dr. Pierre Yves Santiago, Sylvain Mailard, Nathalie Robin Sanchez, and the entire staff. We extend our thanks to the architectural firm AIA Life Designers, and their architects and engineers who participated in the study. We particularly thank Bruno Saint Dizier and Jean-Joseph Rousseau for their involvement. We thank all the patients who took part in the study, as well as the pilot testers. This work is part of the PEEL project (Patient Experience Evaluation Lab) funded by the Pays de la Loire French region through the West Creative Industries program (OIC-2021-PEEL). The comments of anonymous reviewers on an earlier version of this article helped improve its clarity.

Appendix. Generic diachronic and synchronic analysis

Table A.3 shows which participant experienced which dimension of experience. For example, as seen in [Fig. 8](#), VR1 experienced *Disorientation* (which is a sensation), and *Apprehension* (which is an emotion) during the normalized moment *At the start*; *Stress* and *Anxiety* during the moment *Ticket terminal*, as well as *Perception of other patients* (Social perception) during the moment *Entering the waiting room*. This translates in [Table A.3](#) as the presence of VR1 on the line *Ticket terminal* for *Emotion* and *Sensation* dimensions, as well as *Emotion*, *Sensation*, and *Social perception* for *At the start*. When there was a synchronic category in a sub-moment, we considered it also describes its upper moment. Some rows of the Table are empty, which means that we did not find any synchronic categories for the corresponding moments. Yet, these rows exist because at least one participant still described lived experience corresponding to it.

Table A.3

Result of the generic diachronic and synchronic analysis for normalized moments and dimensions of experiences. Columns 1 and 2 represent all the normalized moments; the other columns correspond to specific participants describing at least one experiential synchronic category corresponding to a dimension in this moment or its sub-moments. Note that we also collected experiences outside the episodes (gray cells) we focused on.

Generic diachronic moments		VR Group					Reality Group				
Level 1	Level 2	Thought	Emotion	Sensation	Direct percept.	Social percept.	Thought	Emotion	Sensation	Direct percept.	Social percept.
1. At the start		VR3	VR1	VR1,VR5		VR1		R4,R2 R6	R7		R2
	1.1 Ticket terminal	VR3	VR1	VR1				R2,R6			R6
2. In the waiting room		VR8			VR5	VR4	R1,R3 R7	R1	R2,R7	R2 R3	R2 R3
	2.1 Waiting#1		VR8				R3	R1			
3. At the nurses' box		VR7				VR1,VR5 VR6	R4		R1 R3	R5,R7	
4. On the sofa		VR7	VR1,VR4	VR4,VR8		VR5	R7		R1		
5. From sofa to stretcher		VR5	VR5	VR1,VR3 VR5,VR7 VR8		VR3,VR5 VR6	R3,R4 R5,R6		R2,R3 R5		R1,R5 R6
6. Sitting in the stretcher		VR1,VR3 VR5,VR6 VR7,VR8	VR1,VR3 VR4	VR1,VR2 VR5,VR6 VR8	VR1,VR2 VR3,VR5 VR6,VR7	VR1,VR2 VR3,VR4 VR5,VR6 VR7,VR8	R2,R3 R4,R5 R7,R8	R1,R4 R5	R2,R3 R4,R5 R6,R8	R1,R3 R4,R5 R7,R8	R1,R2 R3,R4 R5,R6 R7,R8
	6.1 Surgery preparation#1	VR3,VR4 VR7,VR8	VR3,VR4	VR2,VR8	VR7	VR1,VR2 VR3,VR4 VR6	R4,R5 R7,R8	R1,R4 R5,R6	R2,R4 R7	R4,R7 R8	R1,R2 R3,R4 R5,R6
7. To the anaesthesia		VR3,VR4 VR5,VR7	VR6	VR1,VR2 VR3,VR4 VR5,VR7	VR4 VR5		R2,R3 R4,R5 R7 R8	R3	R3,R4 R5,R7 R8	R3,R4 R5,R7 R8	R4,R7 R8
	7.1 Put in a lying position	VR3	VR8	VR3,VR4	VR4		R5		R4	R5	
8. At the anaesthesia place		VR6	VR5,VR8	VR1,VR2 VR5,VR7	VR1,VR4 VR5,VR6 VR7	VR1,VR4 VR5	R1,R2 R3,R4 R5,R6 R7,R8	R1,R3 R4,R7	R1,R2 R4,R5 R6,R7 R8	R1,R2 R3,R4 R5,R7 R8	R5,R8
	8.1 Surgery preparation#2	VR8		VR2,VR5	VR6	VR5,VR8	R3,R6 R7,R8	R1,R4 R7	R3,R5 R6,R7 R8	R1,R3 R4,R5	R5,R6
	8.2 Waiting for operation			VR7,VR8	VR6	VR7,VR8	R3,R4 R5,R6	R3	R4,R6	R3,R4 R5	
9. In the operating room		VR2	VR6	VR1	VR5	VR4	R1,R2 R3,R7	R1,R3 R7	R1,R7	R1,R6 R7	R2,R7
10. Leaving operating room					VR6	VR6					
11. During post anesthesia monitoring		VR2,VR3 VR6,R7 VR8	VR1,VR3 VR6	VR3,VR5 VR7,VR8	VR4,VR5 VR7	VR4,VR6 VR7	R1,R2 R3,R5 R8	R1,R2 R5,R6	R1,R2 R3,R7 R8	R3 R5,R7 R8	R1,R3 R5,R7 R8
12. From the stretcher to the snack room		VR2,VR3 VR8		VR2,VR4 VR8	VR4	VR5	R1,R5		R1,R5	R1,R5 R6	R8
	12.1 Towards lockers	VR2		VR2					R5		
	12.2 At the lockers			VR2		VR5					
	12.3 Towards snack room			VR4	VR4	VR6					
13. In the snack room		VR2,VR3	VR3		VR6	VR6	R6,R8		R1,R3 R6,R7	R1,R2 R3,R7	R3,R6 R7
14. Exit procedures											

Table A.4
Results for the SP-IE questionnaire (for the VR Group).

Participant # (VR Group)	1	2	3	4	5	6	7	8	Mean	SD
Perceived spatial presence (out of 20)	19	16	16	20	15	20	17	13	17	2,51
Affordance of the environment (out of 20)	20	13	20	18	14	18	15	14	16,5	2,83
Enjoyment of the participant (out of 15)	15	14	8	15	12	15	12	11	12,75	2,49
Realness attributed to the environment (out of 15)	15	10	14	11	12	13	12	10	12,13	1,81
Attention allocated to the task (out of 10)	10	10	10	10	8	10	8	9	9,38	0,92
Perceived cybersickness (out of 10)	2	3	4	2	4	8	5	6	4,25	2,05
Social presence of avatars (out of 10)	10	8	8	10	x	10	4	8	8,29	2,14

References

- Abras, C., Maloney-Krichmar, D., Preece, J., et al., 2004. User-centered design. In: Bainbridge, W. (Ed.), *Encyclopedia of Human-Computer Interaction*. 37, (4), Sage Publications, Thousand Oaks, pp. 445–456.
- Alizadehsalehi, S., Hadavi, A., Huang, J.C., 2020. From BIM to extended reality in AEC industry. *Autom. Constr.* 116, 103254. <http://dx.doi.org/10.1016/j.autcon.2020.103254>.
- Azhar, S., Khalfan, M., Maqsood, T., 2012. Building information modeling (BIM): now and beyond. *Australas. J. Constr. Econ. Build.* 12 (4), 15–28. <http://dx.doi.org/10.5130/AJCEB.v12i4.3032>.
- Bødker, S., 2006. When second wave HCI meets third wave challenges. In: *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles*. NordiCHI '06, Association for Computing Machinery, New York, NY, USA, pp. 1–8. <http://dx.doi.org/10.1145/1182475.1182476>.
- Boletsis, C., Cedergren, J.E., 2019. VR locomotion in the new era of virtual reality: an empirical comparison of prevalent techniques. *Adv. Hum.-Comput. Interact.* 2019, <http://dx.doi.org/10.1155/2019/7420781>.
- Brakus, J.J., Schmitt, B.H., Zarantonello, L., 2009. Brand experience: what is it? How is it measured? Does it affect loyalty? *J. Mark.* 73 (3), 52–68. <http://dx.doi.org/10.1509/jmkg.73.3.052>.
- Bridges, A., Charitos, D., 1997. On architectural design in virtual environments. *Des. Stud.* 18 (2), 143–154. [http://dx.doi.org/10.1016/S0142-694X\(97\)85457-9](http://dx.doi.org/10.1016/S0142-694X(97)85457-9).
- Buchenau, M., Suri, J.F., 2000. Experience prototyping. In: *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '00)*. New York, USA, pp. 424–433. <http://dx.doi.org/10.1145/347642.347802>.
- Bullinger, H.-J., Bauer, W., Wenzel, G., Blach, R., 2010. Towards user centred design (UCD) in architecture based on immersive virtual environments. *Comput. Ind.* 61 (4), 372–379. <http://dx.doi.org/10.1016/j.compind.2009.12.003>.
- Cahour, B., Salembier, P., Zouinar, M., 2016. Analyzing lived experience of activity. *Le Travail Humain* 79 (3), 259–284. <http://dx.doi.org/10.3917/th.793.0259>.
- Chester, M.R., Rys, M.J., Konz, S.A., 2002. Leg swelling, comfort and fatigue when sitting, standing, and sit/standing. *Int. J. Ind. Ergon.* 29 (5), 289–296. [http://dx.doi.org/10.1016/S0169-8141\(01\)00069-5](http://dx.doi.org/10.1016/S0169-8141(01)00069-5).
- Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhhoshkar, M., Rahimian, F.P., 2020. Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: a proof of concept study. *Front. Eng. Manag.* 7 (3), 396–403. <http://dx.doi.org/10.1007/s42524-019-0039-y>.
- Delarue, S., Hoppenot, P., Colle, E., 2006. UCD Method using VR and related techniques for designing complex system. In: *Proceedings of Virtual Concept 2006*. Cancun, Mexico, pp. 1–12, URL <https://hal.science/hal-00341302>.
- Depraz, N., Gyemant, M., Desmidt, T., 2017. A first-person analysis using third-person data as a generative method. *Constr. Found.* 12, 190–203, URL <http://constructivist.info/12/2/190.depraz>.
- Depraz, N.E., Varela, F.J., Vermersch, P.E., 2003. *On Becoming Aware: a Pragmatics of Experiencing*. John Benjamins Publishing Company, <http://dx.doi.org/10.1075/aicr.43>.
- Doan, D.T., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Rehman, A.U., Tookey, J., Ghaffarianhoseini, A., 2019. What is BIM? A need for a unique BIM definition. In: *MATEC Web of Conferences*. 266, EDP Sciences, p. 05005. <http://dx.doi.org/10.1051/mateconf/201926605005>.
- Dorta, T., Kinayoglu, G., Hoffmann, M., 2016. Hyve-3D and the 3D cursor: Architectural co-design with freedom in virtual reality. *Int. J. Archit. Comput.* 14 (2), 87–102. <http://dx.doi.org/10.1177/1478077116638921>.
- Doyle, C., Lennox, L., Bell, D., 2013. A systematic review of evidence on the links between patient experience and clinical safety and effectiveness. *BMJ Open* 3 (1), e001570. <http://dx.doi.org/10.1136/bmjopen-2012-001570>.
- Drettakis, G., Roussou, M., Reche, A., Tsingos, N., 2007. Design and evaluation of a real-world virtual environment for architecture and urban planning. *Presence: Teleoperators Virtual Environ.* 16 (3), 318–332. <http://dx.doi.org/10.1162/pres.16.3.318>.
- Evrard, R., Lazrak, N., Laurent, M., Toutain, C., Le Maléfian, P., 2018. Du moi vif des noyés à l'expérience de mort imminente: approche clinique d'une énigme médico-psychologique à partir d'un nouveau cas. In: *Annales MÉDico-Psychologiques, Revue Psychiatrique*. 176, (2), pp. 189–198. <http://dx.doi.org/10.1016/j.amp.2016.10.016>.
- Flanagan, J.C., 1954. The critical incident technique. *Psychol. Bull.* 51 (4), 327. <http://dx.doi.org/10.1037/h0061470>.
- Françoise, J., Candau, Y., Fdili Alaoui, S., Schiphorst, T., 2017. Designing for kinesthetic awareness: revealing user experiences through second-person inquiry. In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. Denver, Colorado, USA, pp. 5171–5183. <http://dx.doi.org/10.1145/3025453.3025714>.
- Fuchs, P., 2006. *Le traité de la réalité virtuelle*. 2, Presses des MINES, URL <https://minesparis-psl.hal.science/hal-00753715>.
- Hassenzahl, M., Tractinsky, N., 2006. User experience—a research agenda. *Behav. Inf. Technol.* 25 (2), 91–97. <http://dx.doi.org/10.1080/01449290500330331>.
- Heavey, C.L., Hurlburt, R.T., 2008. The phenomena of inner experience. *Conscious. Cogn.* 17 (3), 798–810. <http://dx.doi.org/10.1016/j.concog.2007.12.006>.
- Heydarian, A., Carneiro, J.P., Gerber, D., Becerik-Gerber, B., Hayes, T., Wood, W., 2015. Immersive virtual environments versus physical built environments: A benchmarking study for building design and user-built environment explorations. *Autom. Constr.* 54, 116–126. <http://dx.doi.org/10.1016/j.autcon.2015.03.020>.
- Høffding, S., Heimann, K., Martiny, K., 2022. Working with others' experience. *Phenomenol. Cogn. Sci.* 1–24. <http://dx.doi.org/10.1007/s11097-022-09873-z>.
- Hogan, T., Hinrichs, U., Hornecker, E., 2015. The elicitation interview technique: Capturing people's experiences of data representations. *IEEE Trans. Vis. Comput. Graph.* 22 (12), 2579–2593. <http://dx.doi.org/10.1109/TVCG.2015.2511718>.
- Hong, T., Lee, M., Yeom, S., Jeong, K., 2019. Occupant responses on satisfaction with window size in physical and virtual built environments. *Build. Environ.* 166, 106409. <http://dx.doi.org/10.1016/j.buildenv.2019.106409>.
- Houde, S., Hill, C., 1997. What do prototypes prototype? In: *Handbook of Human-Computer Interaction (2nd Ed.)*. Elsevier, Amsterdam, NL, pp. 367–381. <http://dx.doi.org/10.1016/B978-044481862-1.50082-0>.
- Igarzábal, F.A., Hruby, H., Witowska, J., Khoshnoud, S., Wittmann, M., 2021. What happens while waiting in virtual reality? A comparison between a virtual and a real waiting situation concerning boredom, self-regulation, and the experience of time. *Technology, Mind, and Behav.* 2 (2), <http://dx.doi.org/10.1037/tmb0000038>.
- Kalantari, S., Neo, J.R.J., 2020. Virtual environments for design research: Lessons learned from use of fully immersive virtual reality in interior design research. *J. Interior Des.* 45 (3), 27–42. <http://dx.doi.org/10.1111/joid.12171>.
- Kalantari, S., Rounds, J.D., Kan, J., Tripathi, V., Cruz-Garza, J.G., 2021. Comparing physiological responses during cognitive tests in virtual environments vs. in identical real-world environments. *Sci. Rep.* 11 (1), 10227. <http://dx.doi.org/10.1038/s41598-021-89297-y>.
- Kamat, V.R., Martinez, J.C., 2001. Visualizing simulated construction operations in 3D. *J. Comput. Civ. Eng.* 15 (4), 329–337. [http://dx.doi.org/10.1061/\(ASCE\)0887-3801\(2001\)15:4\(329\)](http://dx.doi.org/10.1061/(ASCE)0887-3801(2001)15:4(329)).
- Khenak, N., Vézien, J.-M., Bourdot, P., 2019. The construction and validation of the SP-IE questionnaire: an instrument for measuring spatial presence in immersive environments. In: *Virtual Reality and Augmented Reality*. EuroVR 2019. LNCS 11883, pp. 201–225. http://dx.doi.org/10.1007/978-3-030-31908-3_13.
- Kuliga, S.F., Thrash, T., Dalton, R.C., Hölscher, C., 2015. Virtual reality as an empirical research tool—Exploring user experience in a real building and a corresponding virtual model. *Comput. Environ. Urban Syst.* 54, 363–375. <http://dx.doi.org/10.1016/j.compenurbysys.2015.09.006>.
- Leicht, R.M., Abdelkarim, P., Messner, J.I., 2010. Gaining end user involvement through virtual reality mock-ups: a medical facility case study. In: *Proceedings of CIB W78 2010 - Applications of IT in the AEC Industry*. 78, Cairo, Egypt, pp. 1–8, URL <http://itc.scix.net/paper/w78-2010-143>.
- Light, A., Cahour, B., Otero, N., 2010. Reflections on reflection: how critical thinking relates to collecting accounts of experience using explicitation techniques. In: *Proceedings of the workshop on Critical Dialogue: Interaction, Experience and Cultural Theory at CHI '10*. Atlanta, Georgia, USA., URL <https://shura.shu.ac.uk/id/eprint/4042>.
- Lim, K., Lee, J., Won, K., Kala, N., Lee, T., 2021. A novel method for VR sickness reduction based on dynamic field of view processing. *Virtual Real.* 25, 331–340. <http://dx.doi.org/10.1007/s10055-020-00457-3>.

- Lim, Y.-K., Stolterman, E., Tenenberg, J., 2008. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Trans. Comput.-Hum. Interact.* 15 (2), 1–27. <http://dx.doi.org/10.1145/1375761.1375762>.
- McCurdy, M., Connors, C., Pyrzak, G., Kanefsky, B., Vera, A., 2006. Breaking the fidelity barrier: an examination of our current characterization of prototypes and an example of a mixed-fidelity success. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*. Montréal, Québec, Canada, pp. 1233–1242. <http://dx.doi.org/10.1145/1124772.1124959>.
- McLaughlan, R., Liddicoat, S., 2018. Evidence and affect: employing virtual reality to probe what's missing from evidence-based design research. *Des. Health* 2 (2), 285–304. <http://dx.doi.org/10.1080/24735132.2018.1541432>.
- Meehan, M., Insko, B., Whitton, M., Brooks Jr., F.P., 2002. Physiological measures of presence in stressful virtual environments. *Acm Trans. Graph. (Tog)* 21 (3), 645–652. <http://dx.doi.org/10.1145/566654.566630>.
- Mei, Y., Li, J., de Ridder, H., Cesar, P., 2021. Cakevr: a social virtual reality (vr) tool for co-designing cakes. In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. Article 572, Yokohama, Japan, pp. 1–14. <http://dx.doi.org/10.1145/3411764.3445503>.
- Merhi, O., Faugloire, E., Flanagan, M., Stoffregen, T.A., 2007. Motion sickness, console video games, and head-mounted displays. *Hum. Factors* 49 (5), 920–934. <http://dx.doi.org/10.1518/001872007X230262>.
- Müller, M., Günther, T., Kammer, D., Wojdzak, J., Lorenz, S., Groh, R., 2016. Smart prototyping-improving the evaluation of design concepts using virtual reality. In: *Proceedings of the conf. on Virtual, Augmented and Mixed Reality. VAMR 2016. LNCS 9740*, pp. 47–58. http://dx.doi.org/10.1007/978-3-319-39907-2_5.
- Mütterlein, J., 2018. The three pillars of virtual reality? Investigating the roles of immersion, presence, and interactivity. In: *Proceedings of Hawaii International Conference on System Sciences (HICSS 2018)*. Hawaii, USA, pp. 1407–1415. <http://dx.doi.org/10.24251/HICSS.2018.174>.
- Narciso, D., Melo, M., Raposo, J.V., Cunha, J., Bessa, M., 2020. Virtual reality in training: an experimental study with firefighters. *Multimedia Tools Appl.* 79 (9), 6227–6245. <http://dx.doi.org/10.1007/s11042-019-08323-4>.
- National BIM Standard-United States, 2015. *National BIM standard-United States® version 3*.
- Nielsen, J., 1990. Paper versus computer implementations as mockup scenarios for heuristic evaluation. In: *Proceedings of the IFIP TC13 Third International Conference on Human-Computer Interaction (INTERACT '90)*. North-Holland Publishing Co., NLD, pp. 315–320, URL <https://dl.acm.org/doi/10.5555/647402.725312>.
- Norman, D.A., 2002. *The Design of Everyday Things*. Basic Books, New York, URL <https://mitpress.mit.edu/9780262525671/the-design-of-everyday-things/>.
- Oijevaar, K., Jovanovic, M., Den Otter, A., 2009. User involvement in the design process of multifunctional buildings. In: *Changing Roles: New Roles and New Challenges (CR09)*. Delft University Press, pp. 485–495, URL <https://research.tue.nl/en/publications/user-involvement-in-the-design-process-of-multifunctional-buildin>.
- Petitmengin, C., Remillieux, A., Valenzuela-Moguillansky, C., 2019. Discovering the structures of lived experience. *Phenomenol. Cogn. Sci.* 18 (4), 691–730. <http://dx.doi.org/10.1007/s11097-018-9597-4>.
- Petitmengin, C., et al., 2009. The validity of first-person descriptions as authenticity and coherence. *J. Conscious. Stud.* 16 (10–11), 252–284, URL <https://hal.science/hal-00434456>.
- Prpa, M., Fdili-Alaoui, S., Schiphorst, T., Pasquier, P., 2020. Articulating experience: reflections from experts applying micro-phenomenology to design research in hci. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*. Honolulu, HI, USA, pp. 1–14. <http://dx.doi.org/10.1145/3313831.3376664>.
- Prpa, M., Tatar, K., Françoise, J., Riecke, B., Schiphorst, T., Pasquier, P., 2018. Attending to breath: exploring how the cues in a virtual environment guide the attention to breath and shape the quality of experience to support mindfulness. In: *Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)*. Hong Kong, China, pp. 71–84. <http://dx.doi.org/10.1145/3196709.3196765>.
- Reinschluessel, A.V., Teuber, J., Herrlich, M., Bissel, J., van Eikeren, M., Ganser, J., Koeller, F., Kollasch, F., Mildner, T., Raimondo, L., Reisig, L., Ruedel, M., Thieme, D., Vahl, T., Zachmann, G., Malaka, R., 2017. Virtual reality for user-centered design and evaluation of touch-free interaction techniques for navigating medical images in the operating room. In: *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '17)*. Denver, Colorado, USA, pp. 2001–2009. <http://dx.doi.org/10.1145/3027063.3053173>.
- Rivière, J.-P., Malo, R., Vinet, L., Prié, Y., 2024. Utiliser l'entretien d'explicitation pour collecter et comparer des expériences vécues en réalité virtuelle : un bilan de deux études. In: *IHM '24: 35e Conférence Internationale Francophone sur L'Interaction Humain-Machine. AFIHM, Paris, France*, pp. 1–14. <http://dx.doi.org/10.1145/3649792.3649795>.
- Rudd, J., Stern, K., Isensee, S., 1996. Low vs. high-fidelity prototyping debate. *Interactions* 3 (1), 76–85. <http://dx.doi.org/10.1145/223500.223514>.
- Seymour, N.E., 2008. VR to OR: a review of the evidence that virtual reality simulation improves operating room performance. *World J. Surg.* 32 (2), 182–188. <http://dx.doi.org/10.1007/s00268-007-9307-9>.
- Seymour, N.E., Gallagher, A.G., Roman, S.A., O'Brien, M.K., Bansal, V.K., Andersen, D.K., Satava, R.M., 2002. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann. Surg.* 236 (4), 458. <http://dx.doi.org/10.1097/00000658-200210000-00008>.
- Swallow, D., Blythe, M., Wright, P., 2005. Grounding experience: relating theory and method to evaluate the user experience of smartphones. In: *Proceedings of the 2005 Annual Conference on European Association of Cognitive Ergonomics (EACE '05)*. Chania, Greece, pp. 91–98, URL <https://dl.acm.org/doi/abs/10.5555/1124666.1124679>.
- Valenzuela-Moguillansky, C., Vásquez-Rosati, A., 2019. An analysis procedure for the micro-phenomenological interview. *Constructivist Foundations* 14 (2), 123–145, URL <https://constructivist.info/14/2/123>.
- Vermersch, P., 1994. *The explicitation interview*. ESF, Paris, URL https://www.academia.edu/36572134/The_explicitation_interview.
- Virzi, R.A., Sokolov, J.L., Karis, D., 1996. Usability problem identification using both low- and high-fidelity prototypes. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '96)*. Vancouver, British Columbia, Canada, pp. 236–243. <http://dx.doi.org/10.1145/238386.238516>.
- Wagler, A., Hanus, M.D., 2018. Comparing virtual reality tourism to real-life experience: Effects of presence and engagement on attitude and enjoyment. *Commun. Res. Rep.* 35 (5), 456–464. <http://dx.doi.org/10.1080/08824096.2018.1525350>.
- Walker, M., Takayama, L., Landay, J.A., 2002. High-fidelity or low-fidelity, paper or computer? Choosing attributes when testing web prototypes. In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 46 (5), Baltimore, USA, pp. 661–665. <http://dx.doi.org/10.1177/154193120204600513>.
- Wall, M.B., Ulrich, K.T., Flowers, W.C., 1992. Evaluating prototyping technologies for product design. *Res. Eng. Des.* 3 (3), 163–177.
- Walsh, K.R., Pawlowski, S.D., 2002. Virtual reality: A technology in need of IS research. *Commun. Assoc. Inf. Syst.* 8 (1), 20. <http://dx.doi.org/10.17705/1CAIS.00820>.
- Witmer, B.G., Singer, M.J., 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence* 7 (3), 225–240. <http://dx.doi.org/10.1162/105474698565686>.
- Wolf, J., 2015. The state of patient experience. *Patient Exp. J.* 2 (2), 1–3. <http://dx.doi.org/10.35680/2372-0247.1113>.
- Xu, C., Demir-Kaymaz, Y., Hartmann, C., Menozzi, M., Siegrist, M., 2021. The comparability of consumers' behavior in virtual reality and real life: a validation study of virtual reality based on a ranking task. *Food Qual. Pref.* 87, 104071. <http://dx.doi.org/10.1016/j.foodqual.2020.104071>.
- Zahedi, M., Guité, M., De Paoli, G., 2011. Addressing user-centeredness: Communicating meaningfully through design. In: *Designing Together: Proceedings of the 14th International Conference on Computer Aided Architectural Design (CAAD Futures)*. Liège, Belgium, pp. 1–12.
- Zielasko, D., Riecke, B.E., 2021. To sit or not to sit in vr: Analyzing influences and (dis) advantages of posture and embodied interaction. *Computers* 10 (6), 73. <http://dx.doi.org/10.3390/computers10060073>.
- Zimmermann, P., 2008. Virtual reality aided design. a survey of the use of VR in automotive industry. In: *Product Engineering*. Springer, Springer, Dordrecht, pp. 277–296. http://dx.doi.org/10.1007/978-1-4020-8200-9_13.