Multi-Agent Scenarios for Training Designers in Healthcare Design

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In this position paper we propose the use of multi-agent extended reality (XR) scenarios to train designers of clinical devices and health care pathways to better understand their context of use. Limitations in healthcare design, e.g., concerning medical devices, interfaces, device use procedures, typically are addressed by training clinical staff to better cope with technology and its context of use. Ideally the impact of health care design on clinical outcomes should be addressed as early as possible during the design of clinical devices and services. Unfortunately, designers' mental models often do not capture the complex procedural, socio-technical, and internal context of use within healthcare ecosystems, resulting in sub-optimal design approaches for clinical care, and design issues being recognized only after clinical devices and procedures are implemented on-site. Our work aims to align designers' mental models of clinical procedures with mental models of clinical users, to improve patient and staff experience, better health outcomes, and lower costs of care.

1 INTRODUCTION

The context of use of clinical devices such as ventilators, magnetic resonance imaging (MRI) scanners, or surgical information technology (IT), is difficult to understand for designers. This is due to the many inter-dependencies between patients, staff, and the physical and technological environment such safety-critical devices are placed in.

Despite this complexity, designers creating clinical devices need to develop a thorough understanding of the procedural context of use (e.g., phases of an MRI scan), the socio-technical context of use (e.g., team interactions with a device or patient behavior), and the internal context of staff and patients (e.g., cognitive models of work or emotional states of patients).

Current design research practices such as design ethnography [13], qualitative studies [11], and the quantification of behavior [4] commonly explore more individual aspects of the context of use through interviews with staff members, observations of patients, or use logs of technical equipment. Further, the produced data and insights are final; designers cannot manipulate the use scenarios they captured, reenact certain aspects of an interaction, or zoom in on an important detail. The analytical nature of use data supports generalizability, but limits the ability to consider and interpret the often "messy" complexity of real life.

For a successful healthcare design the consideration of the socio-technical context, the internal context of staff and patients, and the procedural context are key. Only a thorough understanding enables minimizing errors, assures good patient compliance, and avoids stress-related negative effects on staff, patients, and equipment.

A way to allow designers to familiarize themselves with this complex design space is the usage of digital representations of the medical context. Digital Twins [5] are digital simulations using real life data. Digital twins of clinical contexts combined with extended reality (XR) technologies promise to enable designers to investigate the complex

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interactions between staff, patients, and the work context, and to integrate complex information, holding the promise to provide deeper insights into context of use.

Through simulated context of use in XR, we hope to support designers to quickly immerse themselves in realistic internal-, procedural-, and socio-technological contexts so they can empathize, and therefore design solutions that fit the context, aiming to improve patient experience, better health outcomes, improve staff experience, and lower costs of care (the quadruple aim [2]).

In the following we give an overview of how context of use is currently addressed in healthcare design, discuss our approach to XR as a solution to familiarize designers with such a design space, and conclude with insights on opportunities for healthcare design.

2 RELATED WORK

Design for healthcare uses a range of methods, e.g., human factors engineering, patient journeys, or user-centered design [11]; and tools, e.g., role-playing, digital simulation [13], or task analyses, i.e., charts or tables that list user actions with regard to a product in a formalized way [4]. Structured ways of thinking, specific research approaches, and specialized software shape how design work is planned, executed, and talked about among a design team and their stakeholders.

2.1 Context of Use in Healthcare Design

To design for healthcare, designers need to take on a complex perspective showing awareness for the context of use. We define the context of use as the procedural, socio-contextual, and internal or emotional context clinical devices are used in. Previous explorations of the context of use reveal the value of awareness of the context of use for designers, and of specialized means to communicate the context of use to them [6]. Wooldrige et al. [15], for example, investigate pediatric patient safety through the lens of human factors engineering methods, identifying staff roles and transitions between them during care. Simonse et al. [12] developed service design by documenting patient journeys through diagnostic procedures.

Design approaches to understand the context of use include user-centered design, data-centric design, design ethnography, patient and staff interviews, observations, and co-creation workshops with multiple stakeholders [13]. In healthcare design specifically, hospital visits, staff interviews and staff feedback are common ways for healthcare designers to understand the users of their products and the environment they operate in. However, these methods have certain limitations, importantly that they are labor-intensive, depend on the availability of clinical staff, and can be disruptive to clinical workflows. Other tools to better understand the context of use include 3D animation and simulation [8], role-playing [11] or generative design [14]. While these tools have been shown to be effective in providing designers with insights, they also show limitations regarding the repeatable simulation of interaction under changing conditions, allowing designers to explore aspects of the complexity of the context of use, but not the full range of interactions. These current tools are limited regarding their ability to integrate use data from several simultaneous users and changing contextual information to enable designers to understand the dynamic interactions in the context of use [10].

In later design phases evaluation is crucial, particularly for the development of clinical devices. A commonly used evaluation method in healthcare settings is usability testing. It serves to catch many emergent issues and potential problems of new prototypes, and to improve new systems before they are produced and implemented at scale. In the context of care, usability tests are, for example, simulations of staff interactions with actors or training dolls. Current mock-ups and test bays allow for prototype testing under a range of different contexts. However, scenarios with multiple actors or including wider social and organizational context are more time consuming, logistically effortful, and cost expensive to arrange [10]. Due to these limitations, prototypes of clinical devices are commonly considered and tested in settings that represent only part of their envisioned context of use.

2.2 Simulating Context of Use with XR

Companies and researchers already simulate some medical procedures and experiences with the help of XR technology. Patient training for medical procedures exists in the shape of virtual reality (VR) simulations, games and mobile phone applications, for instance for MRI [7]. There is also staff training for medical procedures, e.g., surgery, that can include immersive VR and physical equipment [1]. These training simulations can enable training for rarer surgical interventions that less experienced surgeons usually cannot practice sufficiently in the real hospital environment. Certain training approaches aim for a training setup in context, like allowing novice surgeons to train their skills in coping with several IT interfaces while performing surgery [9].

Previous work on XR prototype testing suggests that human-technology interactions can be fruitfully studied in simulated environments [3]. However, recent work also suggests that XR prototype testing environments are not sufficiently understood in their features and possibilities yet [8].

3 A NOVEL XR TOOL TO SUPPORT HEALTHCARE DESIGNERS

Goal of our recent research activities is to explore how to support healthcare designers with novel XR tools and practices to enable their improved understanding of the context of use. We envision an XR simulated scenario tool that designers use to align their understanding of clinical procedures and their context more closely with that of clinical users. Our tool will comprise a database of simulated scenarios for a given clinical procedure like an MRI scan. In the simulated scenario, designers experience the procedure from a clinical user's point of view, thus training their understanding of context information. When designers have reached a good understanding of clinical context, we further suggest that simulated scenarios can be used to test digital counterparts of new prototypes within them.

Using multi-agent scenarios to examine the more complex interplay between patients, staff, and the physical and technological environment is a core part of this process. The simulated scenarios could allow designers to collaboratively act out the context of use with a larger diversity of colleagues and simulated staff members and patients. Our research investigates how simulated scenarios can be established, how to represent them virtually, and what the translation between real context of use and XR simulated scenarios means for our approach. The way we are measuring improved understanding of context of use is through designer's mental models of clinical procedures. Our approach is to (1) capture clinical users' mental models of a clinical procedure, (2) capture designers' mental models of that same procedure, and (3) identify divergences between their mental models. Parts that are missing from designers' mental models, and that clinical users consider important for the procedure are then included in a *target designer mental model.* We then perform (4) iterative prototyping to arrive at an XR simulated scenario meant to convey the target designer mental model of the procedure to designers. In (5) an evaluation stage, we assess how the designer mental model has developed, and whether the target designer mental model has been reached through the scenario. Depending on the outcome, iterative prototyping and evaluation are repeated until we reach a simulated scenario that conveys the target designer mental model of the procedure.

Simulated scenarios can allow for exploration and evaluation of complex clinical systems, and clinical device and staff behavior within them, e.g., MRI procedures, using contextual data including different environmental factors, e.g., the daily schedule, and input data from different actors, e.g., staffs' experienced stress, with the goal to gauge outcomes through simulation, e.g., a positive impact on staff stress through more easily cleanable clinical device parts. These simulation outcomes can then inform manipulation of the real-life context, e.g., changing the cleaning schedule or parts of a physical prototype, to investigate how digital observations translate into real-life behavior. This opens up new possibilities for designers to grasp, study, and manipulate different contexts.

Currently, we are establishing simulated scenarios of context of use for magnetic resonance imaging (MRI) scanning procedures. We are exploring what contextual information we aim to simulate in XR scenarios through literature and exploratory interviews with designers of clinical devices at a major healthcare technology company.

In the case of MRI, there are a number of contextual factors that might disrupt the usability or user experience of medical staff with the clinical device they use. Based on exploratory interviews with designers of clinical devices, we have begun gathering social, environmental, cognitive, and practical stressors in MRI context of use. Social stressors for staff can include patients anxious about their exams, hostile patients, repeated interruptions of exams by patients, or issues around hierarchical task distribution within hospital staff structures. Environmental stressors include issues around the spatial environment and the storage of equipment, equipment weight, or room features like a lack of windows leading to an extended lack of sunlight during a shift. Cognitive stressors can be issues like a short-term necessity for clarifications in an MRI scan protocol with another staff member, the need to reschedule an exam due to an outpatient no-show or hospital logistics, or equipment malfunctions that require additional attention to resolve. Practical or physical stressors can be the relocation of immobile patients, the extended use of personal protective equipment (PPE) during long shifts, or issues with intravenous (IV) access lines and IV access replacement.

These can be common issues, but they often do not happen in a scheduled manner, some of them are rare, or they might be affected if an additional observer was present in real life. XR simulation of this contextual information in simulated scenarios, however, would allow designers instant and repeated access to a multitude of these scenarios once they were replicated digitally, even if they occur only rarely or spontaneously in real context of use. Designers could thus train their understanding of the context in a more accessible, replicable way.

4 DISCUSSION

Designers of clinical devices would benefit from more deeply integrating the context of use in their design exploration and prototype evaluation. XR simulated scenarios can allow designers to envision different contexts of use, improve predictions, and train for a deeper understanding of differences and shared features between deployment sites.

In the case of MRI, we have begun generating simulated scenarios by gathering staff stressors connected to MRI from literature, stakeholder interviews, and designer perspectives. Training and evaluation with simulated scenarios would allow designers to consider more aspects of context of use, in particular complex interaction between people, context, and equipment. Ultimately, this would lead to better design outcomes.

We believe there is distinct potential in XR simulation use to train designers in their understanding of context of use in healthcare settings, and allow them to consider their prototypes in simulated scenarios. Bad outcomes can emerge between patients, equipment, clinical staff and context of use. This should be addressed by starting to train designers of medical technology to consider context better, not just by training practitioners to cope with the technology. We consider multi-agent simulated scenarios in XR a promising approach to this.

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