Rehabilitation Meets the Metaverse: Human-Centered Design Applied to TERSICORE XRM

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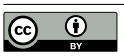
Abstract

This contribution proposes a participatory human-centered design methodology related to *TERSICORE XRM* project conceived to guide the creation of a "MetaRehabVerse", a metaverse-based telerehabilitation system targeting cognitive and sensorimotor recovery. By combining virtual environments with the International Classification of Functioning, Disability, and Health to enhance patient management, the system includes five modules accessible through immersive and non-immersive modalities. Three qualitative research phases engage stakeholders: focus groups with clinicians (Phase 1) and patients (Phase 2) and individual interviews with virtual rehabilitation experts (Phase 3). Data analysis is based on applied thematic analysis to ensure the identification of valuable requirements for system usability, adaptability, and sustainability within healthcare contexts in the early development phases. Findings will inform the development of the *TERSICORE XRM* system and its modules, with the potential for replication in future projects and for evaluating the actual product of the project.



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CCS Concepts

• **Virtual reality**; • **Mixed / augmented reality**; • **User centered design**; • **Participatory design**;

Keywords

Telerehabilitation, Extended reality, Metaverse, Participatory design

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1 Introduction

The metaverse (with augmented reality and virtual reality technologies) [18] is a medium that combines physical and digital experiences [13], various types of 3D technology, real-time collaboration software, and blockchain-based tools [14]. Given the possibilities that the metaverse offers, the funded project *TERSICORE XRM* wants to exploit the metaverse potential in the field of rehabilitation for Parkinson's Disease, mild Dementia, Stroke, Multiple Sclerosis, Traumatic Brain Injury, thus creating a MetaRehabVerse (i.e. integration of the domains of International Classification of

Table 1: Overview of the three participatory design phases of the *TERSICORE XRM* development process

Phase	Participants	Objectives	Data production method	Stimuli/tools	Duration	Modality	Data Analysis
Phase 1	Clinicians (not involved in the project)	Evaluate feasibility and collect insights on concept and modules	Semi-structured focus groups	- System dashboard - Clinician's journey - Module storyboards - Immersive test (HMD[a] + collaborative app)	~2 hours	In-person	Applied thematic analysis [11][d]
Phase 2	Neurological patients (in treatment)	Explore acceptability, usability, and tolerance of XR[b] system	Semi-structured focus groups	- Immersive test (HMD) - Non-immersive test (tablet) - Alternating modalities	~1 hour	In-person	Applied thematic analysis
Phase 3	Academic experts in virtual rehabilitation	Assess conceptual soundness and collect critical feedback	Semi-structured and individual interviews	- Slide-supported presentation of concept and modules	~30 minutes	Online (MS[c] Teams)	Applied thematic analysis

[a] HMD = Head-mounted display.

[b] XR = extended reality.

[c] MS Teams = Microsoft Teams (videoconferencing platform).

[d] A qualitative analysis method used to identify and interpret patterns of meaning in qualitative data.

Functioning, Disability, and Health with those of the metaverse) [13] in line with healthcare financing policies in Italy [7–9].

TERSICORE XRM is conceptualized as a multi-user rehabilitation system divided into five modules that will be used in clinical hospital and home-based setting, delivered in the metaverse via immersive (head-mounted displays, taking into account tolerability [10, 17], cognitive fatigue, and cybersickness [12, 16]), and non-immersive (tablets) modalities. The *TERSICORE XRM* system will be integrated with artificial intelligence algorithm to favor the adequate patients' match.

According to Benyon [4], a positive user experience (i.e., cognitive, affective, and conative aspects regarding an activity) requires that the use of a system is accessible, engaging, and exciting. In this way a system can be produced with an effective stakeholder-centered perspective. *TERSICORE XRM* embraces Benyon's thesis. Consequently, this contribution describes the participatory design approach, involving stakeholders (i.e., clinicians, patients, and academic experts), adopted for the development phases of the modules of *TERSICORE XRM*.

2 Methodology

The research question revolves around evaluating the *TERSICORE XRM* concept by collecting insights from stakeholders to guide the further development phases in terms of feasibility, acceptability and clinical requirements on the four aspects included in Benyon's [4] framework (i.e., people, activities, contexts, technologies).

Table 1 will describe, in brief, the strategic and tactical aspects [5] of research design of the participatory design (three parallel [15] and qualitative phases) adopted for the development phases of *TERSICORE XRM* system. Further details on the three phases are included in the subsections and in Table 2, Table 3, and Table 4.

2.1 Phase 1

Path 1 will present the metaverse test and, after, will present the storyboards. Path 2 will follow the opposite order. Structuring two paths will prevent the influence of effects in evaluating the stimuli due to the order in which the stimuli will be presented. In Path 1, the risk is that a participant will pay no adequate attention to the storyboard because of cybersickness caused by the metaverse test. Each focus group will follow Path 1 or Path 2.

2.1.1 Population and sample. Inclusion criteria: being a clinician working in the field of neurological rehabilitation of clinical conditions.

Sample: 10 clinicians.

2.2 Phase 2

The stimuli will help answer the questions related to the criticalities and strengths. They will also be used to map further aspects (i.e., time spent being immersed in the metaverse, tolerance in alternating immersive and non-immersive modalities, and reactions to collaboration inside the metaverse).

2.2.1 Population and sample. Inclusion criteria: age > 18; diagnosis of a neurological condition such as Parkinson's Disease, mild Dementia, Stroke, Multiple Sclerosis, Traumatic Brain Injury.

Sample: 10 patients.

Table 2: Clinicians' focus group structure

Path 1	Path 2
Introduction	
Staff's presentations and participants' presentations	
Stimulus. Presentation of the system dashboard and clinician's journey	
Investigating system dashboard and clinician's journey in terms of:	
- Criticalities	
- Strengths	
Stimulus. Metaverse test: clinician tries immersive modality with a head-mounted display by using a collaborative application with other participants (*)	Stimulus. Presentation of storyboards of the modules and home-based rehabilitation (**)
(**)	(*)
Investigating using metaverse and collaborative exergames included in the five modules in terms of:	
- Criticalities	
- Strengths	
Investigating home-based rehabilitation as described by the storyboard in terms of:	
- Criticalities	
- Strengths	
Further Participants' comments	
Conclusions	

Table 3: Patients' focus group structure

Path
Introduction
Staff's presentations and participants' presentations
Stimuli. Metaverse test:
- Patient tries immersive modality with a head-mounted display by using a collaborative application with other participants
- Patient uses non-immersive modality with a tablet by using a collaborative application with other participants
- Patient uses alternatively immersive and non-immersive modalities by using the previous two collaborative applications with other participants
Investigating criticalities using immersive modality in terms of:
- With head-mounted display
- With collaborative exergames (having more than one patient connected)
Investigating strengths using immersive modality in terms of:
- With head-mounted display
- With collaborative exergames (having more than one patient connected)
Further Participants' comments
Conclusions

Table 4: Experts' interview structure

Path
Introduction
Stimulus. Presentation of *TERSICORE XRM* concept and modules in brief (supported by slides)
Investigating strengths of contents included in the presentation of the *TERSICORE XRM* concept and modules
Investigating criticalities of contents included in the presentation of the *TERSICORE XRM* concept and modules
Further Participant' comments
Conclusions

2.3 Phase 3

2.3.1 Population and sample. Inclusion criteria: being an expert in virtual rehabilitation (at least three indexed peer-reviewed articles).

Sample: 10 experts.

3 Conclusions

The three phases are an example of data triangulation [1] during a participatory development phase in a funded project.

Challenges regarding this data triangulation are related to organizational aspects (e.g., selection of effective stimuli and recruitment) and conduction of the data production (e.g., technological substrate and cybersickness). However, the participatory design of the development phase of *TERSICORE XRM* is essential to work in the sense of usability engineering [2] and user-centered design [3] that could guarantee, in addition, social usability (i.e., usability that can be taken into account the organizational aspects linked to the product that is at the center of design [6]) of the project modules.

In terms of future implications, the presented participatory design could be replicated and stimuli can be replaced by the modules realized by the technical partner after the development phase, and it could be an example for similar and future projects.

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