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The Reality of Implementing Virtual Reality: A Case Study on the Challenges of Integrating VR-Based Rehabilitation

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Abstract. This paper describes an explorative case study that investigates the declining use of a bespoke VR-based treatment tool for biking-based rehabilitation, through interviews with four physiotherapists and in situ observations of patient-therapist interactions, in a Danish municipal outpatient health center. Thematic analysis was used to identify pain points and challenges related to the integration of VR in both hardware, software and operation resources. Prospective solutions are proposed to increase usability of the system. Moreover, site-specific proposals, including knowledge translation and co-production initiatives, are suggested to increase the health worksforce's incentive to use the VR-supplied service, and endorse it to the patients who attend treatment in the health center.

Keywords: Virtual reality · Rehabilitation · Applied science · Human-centred design · Integrated health services · Service design

1 Introduction

Throughout the last decades advancements have been made in public health, medical breakthrough and improved quality of living, which have contributed to people living longer and healthier. According to the latest report from the United Nations Population Division, 2018 became the first time in recorded human history where the worldwide number of people over the age of 65 outnumbered children under 5 years of age [21]. This development is not expected to decline. In fact, the world population is expected to reach 9.7 billion in 2050, where people $\geq$65 will account for approximately one fifth (1.7 billion) [21].

Consequently, healthcare systems around the world are challenged by the rapidly growing older population, an increase of chronic diseases, and the rising cost for the quantity and the types of care being delivered. Recently the World Health Organization (WHO) called for a fundamental paradigm shift as to how health services are funded, managed and delivered to meet the current

and prospective challenges of the diverse range of healthcare-related needs [23]. Central to their proposals is a move towards people-centred and integrated health services, with an emphasis on a continuous and active dialogue between patients and health service providers e.g. [24]. Furthermore, they note that emerging technologies can allow for new types of services that can bring efficient and innovative forms of care [23]. However, change is a necessity of innovation that frequently leads to new challenges that can disrupt existing practices and cause organization turbulence [6]. Moreover, the economic, political and peer-pressure of 'being innovative' can sometimes lead to the rapid adaptation of unproven innovations and poor implementation of new services. Another evolving field with a special focus on service organization and user-involvement is service design. Service design uses, among other methods, a human-centred approach, and strive to use participatory approaches in all stages of the design process or when identifying existing challenges of innovation. Organizational culture has a paramount role when facilitating change, and thus, the health work-force should always be considered when implementing new health services [5,24]. Despite numerous studies using participatory research approaches to understand contextual conditions of health service innovations, most studies focus on the views of the patients [10,18,19,22]. To our knowledge, very few studies deliver insights to the perspectives and views of the healthcare-providing workforce (such as physiotherapists and occupational therapists).

1.1 Context of the case study

The context of this study is framed by an ongoing PhD-project on virtual reality (VR) based rehabilitation in the Danish municipality of Frederiksberg. The project investigates how VR-based rehabilitation and immersive exertion gaming (exergaming) can cultivate intrinsic motivation, increase training intensity and deliver potential analgesic benefits. The municipality invested in the VR equipment, and implemented in 2016, following the supervision of Jon Ram Bruun-Pedersen in two municipality healthcare facilities, consisting of an inpatient care unit offering rehabilitation treatment during admission, and a health center offering outpatient ambulatory rehabilitation. After a period of acclimatization and preliminary testing, the immersive VR (VR-mode), delivered with a high-end Head-Mounted Display (HMD), saw a decline in usage. However, the TV-based version (TV-mode) of the virtual environment (VE) kept being used in the centers in individual therapy as well as for group-based rehabilitation and exercising.

In this paper we investigate the decreasing trend in usage, and evaluate the challenges faced with the integration of a VR-based treatment tool. Furthermore, we seek to identify critical situations which have a negative impact on the process of using the VR therapy. These will need to be prospectively solved in order to increase the health worksforce's incentive to use the VR-supplied service, and endorse it to the patients, in the outpatient health center.

2 Related work

2.1 VR-based rehabilitation

Repetition is a key component in most areas of motor rehabilitation. Paradoxically, repetitive activities are often what causes lackluster performances by patients in rehabilitation contexts due to a lack of motivation, which can lead to non-adherence with the therapy itself [13]. Therefore, the capacity to provide distractions that instill motivation to continually train the same underlying deficit is of major relevance. Furthermore, rehabilitation efficacy is more commonly achieved, when patients are inspired through intrinsically motivating factors. This can be driven by internal rewards, such as pleasure in doing the activity because it is self-rewarding [15]. For example: Zimmerli *et al.* increased patient engagement for motor rehabilitation through exploration of a virtual environment (VE) in augmented, low-immersive VR (desktop-based) [25]; Bruun-Pedersen *et al.* inspired intrinsic motivation in nursing home residents through exploration of restorative virtual environments (RVEs), using both high-immersive VR (head-mounted displays) and desktop variations [2]; Lewis *et al.* sought to motivate training-habits through a game-based rehabilitation intervention for people with stroke [12]; H.G. Hoffman *et al.* has conducted several studies on the non-pharmacological analgesic benefit of VR for the daily care of patients with severe burn injuries [8,20];

In a recent review, Keshner and colleagues examine literature on VR-based rehabilitation from 1996-2018, and conclude that "the community exists through interlinked networks rather than a single, cohesive field of study" [11]. Furthermore, in relation to development and implementation, it is noted that it may happen so quickly, that the evidence for an intervention's efficacy, and establishment of research and development priorities, are often more reactive than proactive [11]. Moremore, they note that interprofessional team-based approaches will likely strengthen the impact of the technology through the implementation process.

2.2 Service design and healthcare

Service design is an evolving field with a keen focus on human-centred approaches to understanding, improving and redefining the relationship between service supplier and receiver within fields such as finance, travel, manufacturing nonprofits, health, education and government [9,17]. Improvement of services and the developing new value proposition based on user needs, are examples of the benefit that service design can provide organizations [17]. Service design is increasingly being valued as an in-house capability for healthcare suppliers. The increasing complexity of an aging population, the need for integrated healthcare solutions and responsive service offers [24] emphasize the need for innovative problem-solving, and a higher inclusion of human-centred design of such services [14], to counter negative associations affiliated with an ongoing adoption, continuous development, and validation studies of a non-matured technology.

Service design also frequently deals with the concepts of touch points and pain points. Touch points are the points of contact between a service provider and the receiver [4]. However, the touch point can also refer to an interaction with an inanimate object such as a building, a website, or in this case, a VR-based treatment tool. A pain point or fail points refers to a specific problem that a receiver of a service may encounter [16]. In this context, we refer to pain points to describe critical situations, and situations generating friction, that e.g. the physiotherapists may encounter when using usual care, TV-mode or VR-mode.

3 Materials and methods

The main purpose of the exploratory case study was to determine the circumstances in which physiotherapists and occupational therapists would decide to use VR as part of the therapy. Additionally, we evaluate the challenges faced with the implementation, including pain points related to the use of VR, through observations and interviews with physiotherapists in the outpatient health center.

3.1 Existing Materials and apparatus

The VR-equipment available to the therapists contains two pairs of Oculus Rift Consumer Version 1 (CV1) headsets, running on a high-end desktop gaming computer. the CV1 furthermore relies on external tracking from one or more motion trackers. The software provided is a set of RVEs consisting of 4 different unique, digitally generated virtual landscapes [3]. These environments can be viewed either on a ultra high definition (UHD) TV screen, or with aforementioned VR equipment. A virtual on-rail locomotion system generates forward momentum, either with a fixed speed mode (i.e. pre-programmed constant speed) or a feedback controlled mode, measuring the angular velocity of the foot-pedals on the training bike, with a custom-build wireless tracker (called GIRO) connected to the computer via wi-fi [7].

3.2 Interview with physiotherapists

A semi-structured interview method was used for the interview with the physiotherapists, but the scope of themes were focused primarily on their experiences of testing and running the VR. The purpose was to gain an understanding of their initial experiences with VR in therapy-sessions, their professional assessment using VR as a physiotherapy tool, the challenges of integrating the usage patterns, how they incorporated VR into their existing work patterns, and the experiences of operating a new type of unfamiliar system.

Four physiotherapists were interviewed separately. Two of them were professionally experienced, while the other two were relatively new to their profession. Each physiotherapist was considered a domain expert, and assigned to a specific specialized area, such as heart and circuit training, cancer rehabilitation, chronic obstructive pulmonary disease (COPD), and geriatric physical therapy.

Furthermore, questions related to the specific details of how they approached procedures related to the VR therapy.

3.3 Observations

Specific points in the physiotherapist's journey were captured through observations. More specifically, using the observer as participant approach i.e. the observer played a neutral role, but the purpose of his presence was of an overt nature to the participants [1]. Observations were conducted through several visits to the health center, over the cause of three weeks. The expected outcome was to understand the context of the physiotherapist's work, including the interactions with their patients and the tasks they had to perform, in order to execute a patient rehabilitation session which included documenting the sequence of their routines. For one of the sessions, six patients with COPD were observed in the biking room, during a 30 minute interval exercise warm-up session that was conducted by the physiotherapist specialized in the area. The observation included the preparations for running the VR experience including the entire sequence of attaching the sensor to the bike and fitting the HMD to the patient's head. Shorter observations were also performed (with a duration between 5 and 15 minutes) interspersed between interviews, in an attempt to determine the accuracy and rigor of the initial observation, as well as gaining an overall impression of the center's general rehabilitation services.

4 Results

Through the explorative case study, we identified several challenges and threads to the continuous use of the VR equipment, as well as probable reasons for why it has not been more successful, in terms of integration of the service. Furthermore, through thematic analysis we have identified four categories in which to organize the data:

1. VR service (user-experience and usability)
2. Attitude and experiences of the therapist
3. Organizational culture
4. Feedback and dissemination

4.1 VR-service: user-experience and usability issues

A full session with VR-mode adds additional steps for the physiotherapist to perform, as preparation and execution when selecting a VR-based or TV based treatment type. These are related to a combination of hardware and/or software tasks, that also account for the identified pain points. The first pain point experienced also relates to the category of organization culture and maintenance of the equipment. To function properly, the pedal-sensors have to be charged daily. The assignment of charging the sensors, has previously been delegated

to the closing shift, but it has not been routinely adhered to. Therefore, physiotherapists intending to use the VR-mode, frequently find that sensors have not been charged. The connection to the GIRO-sensor is crucial for running the virtual environments in feedback-controlled mode (either VR or TV), and a disconnected sensor or depleted battery will cause a system-crash. Therefore, the fixed speed mode is the most frequently used, as it introduces the VE on the TV-screens, with no significant pain points or challenges. This mode does not afford user-feedback in the form of changes in speed based on exertion, thus the fixed speed mode is conveniently left running across multiple sessions, in a comparable manner to that of a non-interactive screen saver.

An additional pain point is added in relation to the VR-mode. i.e. when assisting patients putting on the headset and fitting it for individual head-size, and calibrating it to match the patient's individual interpupillary distance (IPD). In group-based therapy, this results in a biased attention to the one patient trying VR, while other patients are not observed or supervised as the physiotherapist are busy tending to the one trying VR. By comparison, usual care requires only the pre-existing steps already familiar to the therapist (see fig. 1).

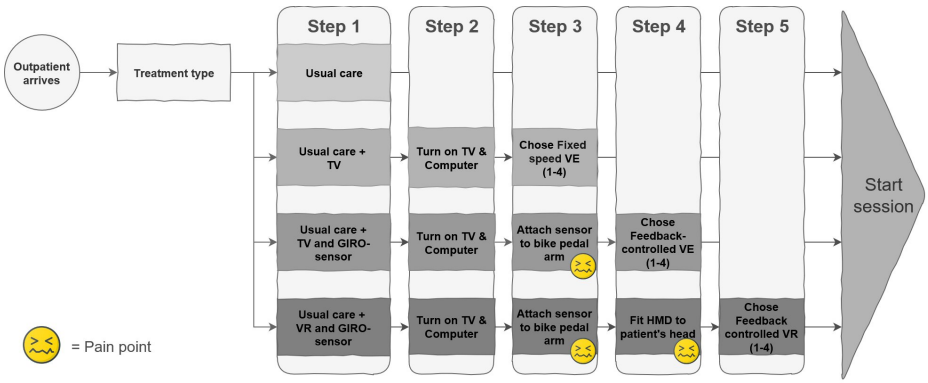

Fig. 1: Task dependency diagram showing the difference in amount of steps required to initiate a therapy with or without TV/VR-based therapy as well as identified pain points. The diagram presents a best-case scenario and does not include additional steps required in case of equipment malfunctions.

Moreover, fig. 1 describes a best case-scenario, but physiotherapists have encountered issues in the form of a series of errors, occurring during the initializing process of the various interconnected components (headset, sensor, TV). This leads to additional steps and causes confusing situations for the physiotherapists, as these errors have been difficult to locate and solve on their own. The errors lead to delays of approximate 5 to 10 minutes, which subsequently cut into crucial patient-time. In relation to memorability, i.e. re-establish proficiency after a break in use, the sequence of the steps in the initializing process can be difficult for the physiotherapist to remember. Confusion can arise in situations when the

set-up has altered since the last interaction, for instance how to strap the sensor to a new pedal arm, or to check the amount of potential reasons for equipment or system malfunctions. This could be anything from a depleted battery, accidental wi-fi IP-address reset, a disconnected cord, or Oculus Rift headset re-calibration requirements due to a shifted motion sensor.

4.2 Attitudes and experience of the therapist

The interviews with the physiotherapists revealed a certain skepticism about the benefits of applying VR to the therapy. This is further intensified by the fact that there is no systematic recording, reporting and evaluations of their collective experiences, related to the use of VR. Furthermore, no clear guidelines exist on the type of patients who could benefit from VR therapy. One physiotherapist suggested that enticement depends much on how the physiotherapist "sells it" to the group of patients in the waiting room. Positive reactions from patients have lead to surprising experience where patients have achieved a seemingly increased training efficacy, which have motivated another physiotherapist to keep recommending it to new patients. However, the use of VR is not at their priority list. The most common reasons given by physiotherapists are: frequently experienced reliability issues related to the technology or due to violations of the protocol (e.g. sensors have not been charged overnight); time pressure due to other strict timetabled tasks; and the extra steps required for setup and preparation of the VR-service.

One therapist uses a careful approach in order to reduce the patients nervousness, by ensuring that the patient can see the monitor first before starting the program, as opposed to having the patient sit with the goggles in pitch darkness, waiting for the physiotherapist to finish the last set-up tasks.

4.3 Organizational culture

The interviews also clarified how the physiotherapists perceived the process of becoming acquainted with the technology. Showcasing of the VR technology has previously been organized by the management, but participation has been voluntary, and not everyone has had the opportunity to try VR themselves. One of therapists suggested that the use of VR eluded, due to a possible correlation between lack of endorsement and self-testing. Furthermore, a hands-on workshop was suggested for everyone, to get a chance to establish familiarity with the technology. New work routines connected to the VR therapy has been outlined and delegated by the center management; most notably, the previously mentioned task of recharging the sensors. However, an additional pain point may arise if the training room has been used for group therapy sessions. In that case therapists wanting to use VR may frequently find exercise bikes being turned away from the VR-setup and TV-monitor. Exercise bikes, weighing as much as 64 kilogram, then has to be rotated 180 degrees before engaging in any other treatment type than usual care.

4.4 Feedback and dissemination

According to the physiotherapists, the feedback they receive from the patients is mostly positive, and many patients find the experience fun and engaging. It is noted that some patients have experiences side-effects (such as nausea, oculomotor disturbances, and disorientation) during use, while others refuse to try it. One physiotherapist reported a near-fall experience which discouraged continuous use. However, overall the consensus was that the VR experiences tend to generate excitement among the patients, and has the capacity to add fun and motivating elements to the conventional therapy. However, currently there is no system in place to record and systematize the emerging collection of physiotherapist observations, experiences and anecdotes of patient-VR interactions (both positive and negative). Moreover, there are no official channels for reporting performance issues. At the moment if there is any handover information, it transports verbally between the therapists or to the functional leader.

5 Discussion

The case study gave valuable insights into specific challenges and helped concretize pain points related to both the functionality and usability of the VR tool, as well as organizational challenges which both needs to be rectified before the bespoke VR-based treatment can be properly integrated.

The current solution requires multiple steps when engaging with it, and each of these steps may be influenced by system errors. The first approach towards improving the system is to reprogram it, so the software itself troubleshoots and guides the user through. For example, through information visualization to indicate where the error might lie, through visualizing whether or not the sensor is detected by the system, or a battery voltage indicator. The lack of charging the sensors has to be embedded into existing work routines. However, from a technological viewpoint, sensors may be improved in relation to battery size and power consumption. The issues with fitting the headset will naturally be more manageable, as therapists become more accustomed with the technology. And future iterations of consumer-grade headsets will likely improve their ergonomics, leading to higher efficiency.

Physiotherapy is essentially a human-centred field, and therapists are motivated by working with patients. Using technology to achieve results is not in itself what drives their interest in the field, and if they use it, the technology has to be easily applicable, easy to learn and straightforward to maintain.

The introduction of VR essentially poses a two-fold challenge for the therapists: They have to familiarize themselves with a brand new technology, but they also need to learn how to integrate it into a specific treatment context which have already pre-established work routines, such as team training workouts. Furthermore, physiotherapy is an evidence-based practice, and there is no designated area where therapists are told that VR will lead to higher efficacy. Nor is there extended knowledge about validity or evidence. Moreover, although

the use of clinical VR is on the rise within healthcare facilities around the world, Denmark has yet to establish national clinical guidelines and recommendations on the use of VR-based rehabilitation.

In relation to communication, there is a need to establish official channels for reporting performance issues, as well as user experiences from patients and therapists alike. Right now, the health center lacks a consistent and periodic evaluation process about the technology. Additionally, some physiotherapists suggest that many of the other therapists are likely unaware of the purpose and goals of the ongoing project. And that many may be weary about using VR, because of 1) lack of knowledge on how to use it, and 2) fear and/or uncertainty about what it may do to the patient (and in what situations it may or may not be beneficial to use). Furthermore, the system has to be practically adapted into the existing interior without the need for heavy relocation of equipment.

VR offers a novel addition to the usual care provided by the health center. If the patients are to engage with the technology, the first step is to make the therapists comfortable with it and address skepticism. Therefore, the therapist is an essential collaborator to involve within all aspects of the design and development process. That can e.g. be approached through e.g. co-production initiatives or knowledge translation (KT) strategies (e.g. interdisciplinary journal clubs).

6 Conclusion

VR is a new world to therapists and patients alike. However, the therapist is an important actor in intermediating the technology to the patients. If the therapists do not have incentive to use it, for example due to a steep learning curve, inadequate usability, or non-established workflow procedures, the technology will not reach a sufficient endorsement and will never consolidate. The VR system has to deliver simple and informative feedback, and work routines need to be clearly defined and visualized. Furthermore, standardized channels for reporting performance issues and user-experiences need to be established and shared with all stakeholders, in order to create an open, transparent and sustained interest in VR-based rehabilitation. Moreover, KT strategies and co-production initiatives should be implemented more systematically to strengthen the impact of the VR-based rehabilitation systems.

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