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A Situation-Specific Theory on the Use of Immersive Virtual Reality in Rehabilitation for Patients With Disabilities

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A primary challenge impeding optimal health outcomes in patients with disabilities is the lack of rehabilitation adherence. Immersive virtual reality emerges as a promising intervention with the potential to significantly enhance this key health outcome. This paper presents a situation-specific theory that outlines the mechanisms through which immersive virtual reality can promote rehabilitation adherence. Outcomes of immersive virtual reality encompass psychological (ie, motivation, self-efficacy, mood state) as well as physical responses (ie, pain management, muscle strength). Mechanisms by which immersive virtual reality influences outcomes are explained by proximal and distal mediators (attention, sense of presence, enjoyment). Possible moderators of these mechanisms (ie, age, gender, social support, trust in technology, cognitive status) are also described. **KEY WORDS:** *adherence, conceptual model, rehabilitation, situation-specific theory, virtual reality Holist Nurs Pract* 2025;39(2):71–79

INTRODUCTION

Improvement in overall survival and the ageing of the population are the 2 main factors behind the increase in disability worldwide.[1] Globally, more than 1 billion individuals experience some form of disability, which encompasses challenges in 3 primary domains of functioning: (i) impairments, including paralysis or blindness, (ii) limitations of activity, including walking or eating, and (iii) restrictions of participation, caused, for example, by discrimination in employment or transportation. Due to a variety of physical and psychological symptoms, these patients often exhibit frailty, which can be countered by specific preventive strategies, with rehabilitation as the primary focus.[2]

Rehabilitation is a collaborative process that involves patients, informal caregivers (ie, family members and friends who care for the patient), and health care professionals. The aim is to optimize well-being by addressing impairments, limitations, and restrictions due to disability.[3] Despite the benefits of rehabilitation, poor adherence is the most critical issue encountered during the care of these individuals.[4]

Adherence to rehabilitation is defined as the degree to which patients follow the instruction for the prescribed treatment. The ability to optimally adhere to treatment plans is frequently jeopardized by intrapersonal variables, clinical factors, therapy-related barriers, social and organizational factors.[4] Interventions aiming to improve adherence would generate a significant positive return through secondary prevention of adverse health outcomes.[5] Recent research highlights the effectiveness of virtual reality (VR) as a promising intervention for enhancing adherence to various rehabilitation programs.[6-9] There are 3 categories of VR: non-immersive, semi-immersive, and immersive. Non-immersive VR involves the use of a screen for 2D images, audio output, and joysticks, while semi-immersive VR adds body sensors.

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However, these 2 types of VR may be subject to distractions due to their non-fully immersive nature.[10,11] On the other hand, immersive virtual reality (iVR) appears to offer greater potential for health-related purposes. This is because iVR provides high-quality 3D images through an audiovisual headset and controllers, facilitating full interaction and immersion in the virtual environment.[12,13] The use of iVR can lead to an adverse event known as cybersickness, a type of visually induced motion sickness experienced in virtual environments that causes symptoms such as nausea, dizziness, fatigue, and oculomotor disorders. Cybersickness does not seem to be very common in patients, but researchers need to consider it.[14]

Despite the emerging use of iVR in rehabilitation, to date there are no situation-specific theories in the literature to help understand how this intervention works to improve adherence in patients with physical disabilities. Situation-specific theories are 'theories that focus on specific nursing phenomena that reflect clinical practice and are limited to specific populations or particular fields of practice."[15] Since iVR is a nursing intervention directly applicable in a specific clinical setting to promote adherence to rehabilitation, it seems reasonable to use this type of theory as a means to outline the mechanisms by which iVR promotes adherence to rehabilitation in persons with physical disabilities. Therefore, this theory aims to describe the mechanisms by which iVR promotes rehabilitation in this population. Outcomes of iVR are described, along with the mediators and moderators, which are the variables that convey, enhance, or diminish the effect of iVR on health outcomes.

CONCEPTUAL FRAMEWORK

Our theory aligns with the Neuman system model (NSM), which is a nursing theory that encompasses mediators, moderators, and preventive strategies as interventions.[16] In accordance with NSM, we define the key concepts of our theory as follows:

Human being

Human beings are conceptualized as open systems, who are holistically composed of 5 components: physiological, body function, psychological, and developmental variables. This definition helps operationalize the individuals targeted in our theory, specifically those experiencing a physical disability, which is a condition deeply intertwined within these variables.[16] Disability can significantly impact various aspects of an individual's life, including mobility, autonomy, communication, and social participation. Focusing attention on people with disabilities is crucial to promote equality and inclusion in society, with the ultimate purpose of enhancing their quality of life. Additionally, the NSM suggests that humans are immersed in a dynamic system shaped by interactions with internal and external environmental stressors.

Environment

It is defined as a vital component of a system where individuals consistently interact to ensure stability and overall well-being.[16] Environments include an internal one, consisting of forces and influences within the human being, an external one, consisting of forces and influences outside the human being, and a created one, which is unconsciously generated by the human being, serving as a supporting means for protective coping mechanisms.[17] Clinical evidence suggests that exposure to natural environments can significantly enhance the key domains of well-being in patients with disabilities, including quality of life, and physical and mental health.[18] iVR has the capability to replicate various environments, producing a therapeutic impact, including natural settings. These virtual scenarios are essential to improve well-being and facilitate the rehabilitation process.

Health

Health is achieved when human needs are met, while illness arises when they are left unfulfilled.[16] In our theory, a health status is linked to the maximal reduction of the state of disability and is connected to the fundamental phase of rehabilitation. Rehabilitation for patients with disabilities improves quality of life and independence through personalized and multidisciplinary care that involves various health care professionals, including nurses.[3]

Nursing

Nursing consists of interventions aimed at helping people restore, adapt and maintain a stable balance between the person's internal condition and environmental stressors while preserving their energy.[16] iVR is a digital health intervention that can be easily implemented in nursing practice to improve patient

psychological and physical outcomes such as motivation,[19] self-efficacy,[20] mood state,[21] pain management,[22] and muscle strength.[21] Adherence to rehabilitation represents a crucial outcome of nursing care.[9]

DEVELOPMENT OF THE THEORY

We conducted an extensive literature review to gain a more in-depth view of the relationship between iVR use and adherence to rehabilitation and the relationship between iVR and other key physical and psychological outcomes in patients with disabilities. Then we identified both proximal and distal outcomes, classified in our theory as mediators, involved in the use of iVR. Furthermore, in accordance with the literature, we identified moderators, which are variables that influence the strength or direction of the relationship between iVR and adherence. Figure 1 illustrates the key elements of our situation-specific theory.

ASSUMPTIONS

Assumptions are statements that are accepted as guiding truth without necessarily being demonstrated through direct evidence within that specific context.[23] This situation-specific theory includes the following assumptions:

1. Disability negatively affects various physiological, psychological, and developmental variables.
2. Virtual scenarios play a crucial role in promoting well-being by simulating environments.
3. People with disabilities often need rehabilitation to improve quality of life and accelerate optimal recovery.
4. iVR is a digital health intervention that is easily implemented in nursing practice.

PROPOSITIONS

Propositions within a theory are specific statements or declarations that constitute the basic units upon which hypotheses, explanations, or relationships are based.[23] We propose the following propositions to be tested in the field of rehabilitation programmes for patients with disabilities:

1. The proximal mediator of multisensory stimulation and the distal mediators of attention, sense of presence, and enjoyment induced by iVR enhance motivation, self-efficacy, and mood levels.
2. The proximal mediator of multisensory stimulation and the distal mediators of attention, sense of presence, and enjoyment induced by iVR facilitate pain management and increase muscle strength.
3. Higher motivation, self-efficacy, and mood can increase adherence to rehabilitation.
4. Reduction of pain and increased muscle strength can increase adherence to rehabilitation.
5. Better adherence stimulated by iVR acts as a positive reinforcement toward the rehabilitation process.
6. The perceived success of the rehabilitation programme promotes motivation for further adherence, which ultimately improves the outcomes related to disability.
7. Due to the increased presence and lower cybersickness, older adults with disabilities are more

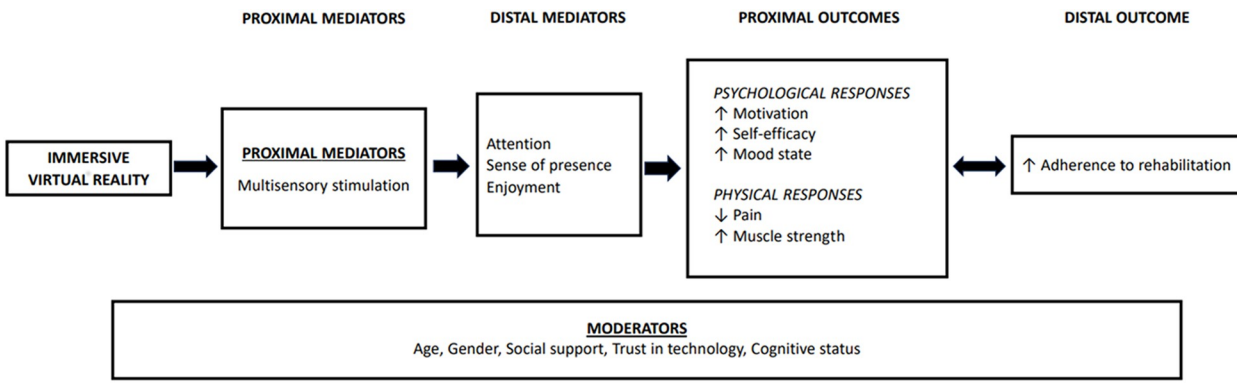

FIGURE 1. Pictorial representation of relationship between immersive virtual reality and adherence to rehabilitation in patients with disabilities.

likely to adhere to iVR compared to younger groups.
8. Due to the lower cybersickness, men are more likely to follow iVR compared to women.
9. Caregivers of patients with disabilities can positively or negatively influence adherence to iVR.
10. The patient's response to iVR is positively influenced by their greater trust in technology.
11. Patient response to iVR is negatively influenced by greater cognitive impairment.

MEDIATORS

Mediators are postulated to convey the effect of iVR on health outcomes and ultimately to rehabilitation and are classified as proximal and distal mediators.

Proximal mediators

Multisensory stimulation

The iVR equipment creates a profound multisensory experience by stimulating the senses of sight, hearing, and touch.[24] Auditory, visual, and tactile neurological impulses enter the brain through specific neural pathways and are processed by neuronal coding.[25] Through a signal recording process, the somatosensory system modifies the perception of images, sounds, and tactile sensations, and renders virtual scenarios as if they were real.[25] At the psychological level, a new state of consciousness is triggered, characterized by a profound immersion generated by the virtual scenarios.[26] This altered state of consciousness neutralizes external environmental stimulus and changes the state of perception of the body in space-time.[26]

Distal mediators

Attention

Due to its potential to engage patients deeply, quickly and comprehensively in virtual scenarios across the senses, iVR technology efficiently redirects attention away from the negative stimuli of hospital environments,[27] because of its ability to engage patients deeply, rapidly and extensively in virtual scenarios across multiple senses.[27] The impact of iVR on the neuropsychological system is explained by the complex dual-task neuropsychological model, which posits that 2 sensory inputs cannot be consciously processed simultaneously. As a result, only 1 stimulus reaches consciousness, while the other remains unconscious for a defined refractory psychological period and may be erased.[28] Because iVR environments provide greater comfort and engagement compared to what is often experienced in health care settings, they effectively satisfy the unconscious desire to accelerate rehabilitation.[29,30] Thus, selective unconscious attention favors iVR sensory input over the hospital environment, leading to the conscious recognition of virtual scenarios through the dorsolateral prefrontal cortex.[31] This neuropsychological condition induces complete sensory isolation, where people lose awareness of their surroundings and become fully immersed in the virtual experience until the iVR session ends. Negative symptoms that arise during the rehabilitation process may be reduced by directing attention to a positively perceived virtual environment. As a result, by counteracting negative stimuli and accentuating happy experiences, iVR can be used as a systematic desensitization strategy.[24]

Enjoyment

Attention toward virtual content is closely related to enjoyment.[32] Influenced by our cultural background, the cognitive process shapes our preferences, desires, and needs, determining whether the virtual environment is enjoyable.[32] A pleasant virtual environment dynamically shifts attention toward iVR content. iVR can increase the enjoyment of physical exercise through specific virtual environments. The perceived enjoyment during the iVR experience acts as a driving force of behavioral intentions and the desire to continue the training.[32] In fact, users who enjoy their iVR experiences are more likely to develop positive perceptions compared to those who do not appreciate this approach. This, in turn, can improve motivation and self-efficacy, consequently increasing adherence to rehabilitation.[32] Interactivity in the virtual environment is a critical aspect for promoting high levels of attention, regardless of any perception of technological mediation. The perception of the elapsed time, known as temporality, is also influenced by enjoyment. The higher the enjoyment in the virtual environment, the higher the speed of perceived time.[24,33]

Sense of presence

The sense of presence denotes a subjective sense of feeling oneself in a reality or a virtual environment, even when physically elsewhere, and responding and acting according to the perceived experience.[34] The

stronger the sense of presence, the more powerful the iVR experience. Place illusion and plausibility are 2 psychological conditions that can arise because of sense of presence.[35] The first is the illusion of perceiving a virtual place as real, while the second is the illusion that the events experienced during iVR are happening, despite being aware they are not happening in physical reality. People respond realistically to iVR when these 2 conditions are present.[35]

PROXIMAL AND DISTAL OUTCOMES

Proximal outcomes influenced by iVR include psychological responses such as motivation, self-efficacy, and mood state, as well as physical outcomes such as pain management and muscle strength (Figure 1).

Psychological responses

Motivation

Motivation is described as the combination of forces that encourage people to act in specific manners and direct and sustain human behavior. Motivation can be extrinsic or intrinsic:[36] extrinsic motivation involves engaging in actions that are driven by an external reward, while intrinsic motivation is related to interest and pleasure accomplished from the activity itself.[37] According to the self-determination theory, engaging in enjoyable, novel and challenging activities increases intrinsic motivation.[38] Because iVR improves enjoyment and satisfaction with rehabilitation treatment,[19] this technology is highly promising in enhancing motivation. Consequently, having higher motivation will also lead to better adherence to rehabilitation, resulting in better outcomes.

Self-efficacy

According to Bandura's theory (1977), self-efficacy, the confidence in our abilities to plan and perform specific tasks, is crucial for adherence.[39] Adherence depends on the belief in one's ability to perform the task and to self-regulate effectively. These beliefs are shaped by various factors, including mastery of experience, substitution of experience, verbal persuasion, and the recognition of bodily signals and body states.[39]

According to the literature, self-efficacy levels can increase during iVR rehabilitation.[40] This is explained by the fact that the immersive experience and enjoyment provided by iVR contribute to better mastery of experience. In addition, iVR can effectively divert attention from health issues, such as pain or discomfort, allowing for the substitution of negative experiences with more positive ones. Furthermore, the iVR serves as a valuable tool for encouraging rehabilitation, as it provides instructive motivational content to help patients. Higher levels of self-efficacy in patients correlate with increased pursuit of goals, adherence to treatment, and persistence in the face of challenges.[20] Individuals with elevated self-efficacy also tend to participate in a greater number of physical activities compared to their counterparts.[20]

Mood state

Physical disability has been linked to mood disorders such as depression and anxiety.[41] Evidence suggests that people with physical limitations are at least 3 times more likely to experience depression and anxiety compared to the general population.[41] According to previous research, the use of iVR during rehabilitation can improve one's mood state.[21] This could be due to the greater attention, sense of presence, and enjoyment that iVR can evoke.

Physical responses

Pain management

Pain is a risk factor that causes patients to stop rehabilitation.[42] According to previous randomized controlled trials, iVR appears to be effective in reducing pain during the rehabilitation of patients with various types of disabilities.[22,43,44] Research has also shown that during the iVR session patients experienced an increase in skin temperature and lower heart rate, which further supports the reduction of pain.[22] Furthermore, compared to standard care, iVR-facilitated pain reduction in patients with chronic neck pain resulted in greater reduction in disability.[42] The mechanisms highlighted in the literature that led iVR to an analgesic effect are undoubtedly greater attention, sense of presence, and enjoyment.[12] Using the analgesic effects of iVR to alleviate painful symptoms can be crucial for enhancing rehabilitation adherence.[42] Although no data are currently available in the literature, we hypothesize that adopting iVR to reduce pain could lead to improving another important outcome in the field of rehabilitation, such as range of motion. The range of motion refers to the extent of movement a joint can achieve from its bent to its extended

positions and plays a crucial role in preserving flexibility, mobility, and overall physical well-being. Restricted range of motion can have a considerable impact on daily activities and increase the likelihood of muscle strain injuries.[45]

Muscle strength

Muscle strength is a fundamental outcome in the field of rehabilitation because it positively predicts basic and instrumental activities of daily living.[46] Evidence on the effectiveness of iVR in improving muscle strength is promising, especially in Parkinson's disease, ankle instability, post-stroke, abdominopelvic rehabilitation of postmenopausal women, and frozen shoulder.[21] The mechanisms that lead to iVR to improve the effect of muscle strength certainly include attention, sense of presence, and enjoyment.[21] Notably, increased muscle strength can lead to faster perception of rehabilitation effectiveness[47]; therefore, patients receive positive biofeedback that could improve adherence to the rehabilitation program.

Distal outcome

Adherence to rehabilitation

Adherence to rehabilitation is not only crucial for the success of the therapeutic pathway, but also has profound implications for physical and mental well-being.[48] In fact, by consistently participating in prescribed exercises and therapies, patients not only address physical impairments, but also experience notable improvements in their mental resilience and overall quality of life.[48]

Using the tangible effects of iVR to engage in psychological outcomes, individuals are driven by a sense of purpose and determination to adhere to their treatment plans. This fosters an essential positive attitude, which is crucial to overcome challenges related to the disability. Furthermore, as patients observe tangible improvements in pain management and muscle strength with iVR, they are further motivated to support their efforts and persevere in the rehabilitation process. The positive feedback loop created by the adherence to the rehabilitation program amplifies these benefits over time. As patients continue to follow their treatment plan, they may notice additional improvements in motivation, self-efficacy, mood, pain management, and muscle strength. This virtuous cycle could reinforce the commitment to rehabilitation, leading to a more comprehensive and effective recovery.

MODERATORS

Moderators are defined as those variables that influence the strength or direction of the relationship between 2 variables.[23] The moderators identified in this theory are age, gender, social support, trust in technology and cognitive status (Figure 1).

Age

Evidence suggests that older people experience greater presence and less cybersickness compared to younger adults. iVR proves to be a viable technology for older adults, offering potential benefits that could exceed those for young adults.[49]

Gender

Gender differences in the use of iVR include women being more susceptible to cybersickness compared to men, due to a narrower interpupillary distance.[50] This anatomical distinction may pose challenges in the fit glasses or optical devices in the iVR. However, gender does not appear to alter the key components of iVR experiences such as attention, enjoyment, and sense perception, but could serve as a reason for discontinuation due to the higher likelihood of cybersickness in women compared to men.[50]

Social support

Social support is linked to rehabilitation outcomes when using iVR. Indeed, caregivers and patient associations can provide support and encouragement to use iVR during rehabilitation. They can also elicit discussions about potential barriers encountered with iVR use and provide assistance through constant exchange of opinions, ideas, and types of support, which enhances motivation for the use of iVR during rehabilitation. In contrast, social support that does not align with the technological proposal can discourage its use.[51]

Trust in technology

In the context of iVR, trust in technology plays a critical role because it shapes the connection between individuals and technologies, ultimately influencing the success of anticipated outcomes. Current research indicates a strong and positive link between satisfaction and trust in iVR. In addition, there is a positive and strong association between the usability of iVR

systems and the trust people place in them. Usability is a potential predictor of trust in iVR.[52]

Cognitive status

Despite the demonstrated benefits of iVR for patients with cognitive disorders,[53] it is also well known that cognitive impairment can expose these patients to risks when using iVR, such as sensory overload, which can cause fatigue, disorientation, confusion, and agitation, particularly in those with learning and adaptation difficulties.[53]

NURSING IMPLICATIONS FOR PRACTICE AND RESEARCH

This situation-specific theory is developed to be immediately applied to clinical practice and research, with feasible empirical validation through the formulated relational propositions. In fact, our theory paves the way for future nursing research aimed at improving adherence to rehabilitation among patients with disabilities, with the goal of improving rehabilitation outcomes, which is a relatively underexplored field. Furthermore, there is a need to standardize iVR interventions in terms of scenario types and duration.[31] This standardization seeks to maximize the effectiveness of iVR interventions and customize them to address specific rehabilitation needs through collaborative efforts between software engineers and nurses.[9]

In addition, this theory provides guidance for clinical practice. Nurses who supervise the rehabilitation of patients with disabilities can integrate iVR into their protocols to improve rehabilitation outcomes and provide confirmation of this theory. Before implementing iVR, it is best to assess cognitive status using validated tools. Furthermore, supervision by nurses of patients suffering from cognitive disorders is essential to ensure a safer rehabilitation experience.[53] Furthermore, for safety reasons, it is important to perform a systematic evaluation of possible cybersickness to iVR after each use of VR through validated tools.

CONCLUSIONS

Adherence to rehabilitation in patients with disabilities is fundamental in the field of public health to achieve better rehabilitation-related outcomes. This situation-specific theory describes the mechanism of iVR applied to rehabilitation, through its proximal and distal neurological mediators, which leads to the attainment of psychological responses (ie, motivation, self-efficacy, and mood state) and physical responses (ie, pain management and muscle strength) and, followed by improvement in adherence. We also describe the moderators, variables that influence the strength or direction of the relationship of these mechanisms (ie, age, gender, social support, trust in technology, cognitive status). Researchers and health care professionals can use this situation-specific theory to understand the relationship between adherence to rehabilitation and iVR. Furthermore, they can employ it to confirm this theory through future clinical studies.

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