Beyond Fun: Players' Experiences of Accessible Rehabilitation Gaming for Spinal Cord Injury

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ABSTRACT

Rehabilitation gaming—play of digital games that incorporate rehabilitation exercises—is a well-known and broadly applicable way to make physical rehabilitation more fun. It can motivate patients with spinal cord injury to engage in exercises that they find boring and can be as effective as traditional physiotherapy. However, patients' needs are not only physical. Rehabilitation also needs to help patients overcome the psychological trauma of spinal cord injury. For patients coping with disability, hopelessness, depression, anxiety, or a loss of identity, rehabilitation gaming may provide benefits beyond making exercise more fun. We asked six participants with spinal cord injury to play three cycling-based rehabilitation games to determine how play might change their experiences of rehabilitation. They said that rehabilitation games may be able to help patients to actively participate in their rehabilitation, help them to rediscover who they are, and show them a better future living with spinal cord injury.

CCS CONCEPTS

• **Human-centered computing → Accessibility technologies**;
• **Applied computing → Computer games**.

KEYWORDS

Accessibility, Digital games, Spinal cord injury, Rehabilitation

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1 INTRODUCTION

Spinal cord injury rehabilitation is a life-long process that requires commitment and motivation [40]. Patients need to perform exercises such as cycling, rowing, and arm ergometry regularly to improve motor function and prevent commonly comorbid diseases [24]. However, patients frequently find these exercises to be boring and may not want to do them [2, 11, 35–37]. For this reason, rehabilitation games—digital games that integrate rehabilitation exercises into play—have been designed around these exercises. These games can make rehabilitation exercises more fun, engaging, and motivating, and can be considered as good as traditional clinical exercise [37].

While the clinical efficacy of rehabilitation gaming has been well established, less is known about how these games can affect patients' experiences of rehabilitation. In some cases, rehabilitation games can be more fun and motivating than the exercises involved in play [16, 36], but making exercise more fun may not do enough to help patients through the ordeal of rehabilitation. For many patients, spinal cord injury is a psychologically traumatic experience that leads to depression, ruminations about their past life, and anxiety about the challenges of living with spinal cord injury [3, 8, 29, 53]. Patients may experience a loss of identity that makes them feel out of place in their own bodies, which are irreparably changed by their injury. For games to meaningfully improve patients' experiences of spinal cord injury rehabilitation, they may need to provide benefits beyond making exercise more fun.

We asked six patients in spinal cord injury rehabilitation to play three cycling-based rehabilitation games in a study to determine how playing games can change patients' experiences of rehabilitation. Two of these games were accessible to all participants, while the other was accessible to only two of six. Participants' accounts of rehabilitation and experiences of playing games while exercising indicate that rehabilitation gaming can provide important benefits beyond making exercise more fun. They said that playing games gave them new ways to actively participate in their rehabilitation, helped them to regulate their negative emotions, and might have helped them to cope with the psychological trauma of injury. Participants believed that rehabilitation gaming could show patients the possibility of a better future with spinal cord injury. One participant said that "[Rehabilitation gaming would be beneficial] *for anyone who, I'd say, has had some sort of injury and thinks that life might be over, but there's still lots to do in life.*" While all participants said that gaming would improve their rehabilitation, they strongly preferred playing games that were fully accessible to them. Participants said that aspects of play that they found disabling diminished their experiences. Another participant had difficulty overcoming one of the games' challenges and said "*That made me focus more on the fact of my deficiency, as opposed to enjoying the game.*" For

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persons with disabilities, physical activities can present barriers to participation [45] and rehabilitation games that are not fully accessible risk making patients feel deficient.

In this paper, we present a thematic analysis of participants' reported experiences of spinal cord injury rehabilitation and playing three cycling-based rehabilitation games. We first review what a spinal cord injury is, how those who have them are rehabilitated, and how patients might experience rehabilitation. We then summarize our study procedure and describe the games that participants played. Finally, we present the results of our analysis and discuss their implications for the use of rehabilitation gaming in spinal cord injury rehabilitation. Our work makes two major contributions: it provides (1) insights into patients' experiences of playing games in spinal cord injury rehabilitation and (2) insights into how accessible rehabilitation gaming can change patients' experiences of spinal cord injury rehabilitation.

2 BACKGROUND

Motor impairments caused by a spinal cord injury can prevent those who have them from living their lives the way they used to. Through rehabilitation exercise, persons with spinal cord injury can regain some of the sensorimotor function and independence they have lost. In this section, we summarize the effects and rehabilitation of spinal cord injury, the use of games to make rehabilitation exercises more enjoyable, and the experiences of patients' going through rehabilitation.

Figure 1: A man with tetraplegia playing a rehabilitation game while passively cycling using a *MOTOmed viva2* pedalling device (shown on the left). His boots are secured to the device's pedals while it performs passive range-of-motion exercise for him.

2.1 Spinal Cord Injury Rehabilitation

When a person's spinal cord is injured, their sensorimotor function is impaired below the point of injury [24, 27, 46] and they need lifelong rehabilitation to improve their health and independence [40]. Spinal cord injury results in either tetraplegia or paraplegia, depending on which portions of the spinal cord are injured [27]. Paraplegia is caused by injury to the sacral, lumbar, or thoracic segments of the spine and impairs motor function in the legs, pelvis, and trunk. Tetraplegia, which is caused by injury to the cervical spine, results in impaired motor function in the legs, pelvis, trunk, and arms. The extent to which motor function is impaired varies by person, ranging from minor impairment to complete paralysis in the affected regions. The American Spinal Injury Association Impairment Scale (AIS) classifies the sensory and motor impairment resulting from spinal cord injury as either complete or incomplete, assigning a letter grade from A (complete loss of sensation and motor function) to E (normal sensory and motor function) [46]. A person with a new injury is typically admitted to a hospital for inpatient rehabilitation in the months following their injury.

Immediately after injury, persons with spinal cord injury can improve their sensorimotor function through exercise [23, 24]. After one year, some enter neurological stability, meaning that no further improvement will be made, although persons with incomplete injuries may continue to improve [19, 50]. Exercises such as walking, cycling, rowing, wheelchair ergometry, and arm ergometry are used in inpatient rehabilitation, immediately after the injury, to improve patients' functional performance while they still can. However, many persons with spinal cord injury have complete paralysis in their legs and are unable to actively contribute to lower-limb exercises. For these patients, passive range-of-motion exercises are used to provide therapeutic activation of their leg muscles [40]. These exercises are performed by either a caregiver, such as a physiatrist or physiotherapist who moves the patient's legs manually, or a motorized device, such as the *MOTOmed viva2* cycling device (shown in Figure 1), that moves the patient's legs mechanically. Devices such as the viva2 are widely used in spinal cord injury rehabilitation; however, cycling may be seen as boring by patients, regardless of whether they can pedal for themselves. To improve patients' experiences of exercises they see as boring, games have been designed specifically for spinal cord injury rehabilitation.

2.2 Experiences of Spinal Cord Injury Rehabilitation

A traumatic spinal cord injury can be a life-altering event that prevents the person who is injured from living the life they lived before. Bourke et al. analyzed interviews with patients with tetraplegia, who were recently discharged from inpatient rehabilitation, and found that they saw spinal cord injury as a "biographical disruption." [3] Other researchers, as well, have reported that patients may believe that the lives they knew before their injury are over and that they may feel out of place in their changed bodies [53]. Patients may come to distinguish their "nondisabled", "internal" selves from their newly "disabled", "external" selves [53]. This can make rehabilitation a depressing experience, filled with ruminations about activities that are no longer accessible and uncertainty about the future, that leaves patients feeling alienated by others and from themselves [8, 53]. For patients to reintegrate themselves into their bodies, they need to be motivated to overcome the challenges of life outside rehabilitation, to reconnect their past lives with the present, and to envision a future that is better than the bleak situation they find themselves in [29, 53]. Caring rehabilitation staff, supportive peers with spinal cord injury, and leisure activities can

help patients make this transition by enabling them to discover what living with spinal cord injury means and showing them that they can still enjoy their lives [8].

2.3 Spinal Cord Injury Rehabilitation Gaming

Spinal cord injury rehabilitation seeks to improve patients' physical capacity and functional performance so that they can live healthy lives with independence [22, 24, 28]. However, this requires patients to perform exercises that are often considered "boring" and "monotonous." [1, 2, 36–38, 41] Rehabilitation games can improve patients' experiences of exercising by incorporating rehabilitation exercises into players' control of the games. Here, we present three classes of rehabilitation games designed to help players improve their functional performance and physical capacity.

2.3.1 Balancing and Reaching Games. Both paraplegia and tetraplegia cause motor impairment in the hips and trunk [24, 27, 46], which can make balancing and reaching tasks more difficult [1, 2]. Balancing and reaching rehabilitation games turn these, possibly uncomfortable [2], movements into game controls. For example, *Wii Fit* [30, 32, 52] and similar standing [1] and sitting [2] balance games use pressure sensors that players activate by leaning to control the games. Reaching games use camera-based motion sensors to play games that involve reaching out and touching virtual objects superimposed over video of the player [13, 28]. These games provide players fun and compelling ways to train functional motor skills, thereby improving players' quality of life.

2.3.2 Shoulder Mobility Games. *Skyfarer* is a mixed reality game that integrates exercises from the STOMPS protocol, a shoulder exercise program for manual wheelchair users [39], into the player's control [15–17]. Players navigate the game world in a seafaring vessel [16] by performing rowing, external rotation, diagonal pull-down, and vertical lift exercises [15] using resistance bands [17]. The shoulder exercises that players perform control in-game activities that mirror the player's physical movements. For example, players row to move their vessel forward and do external rotation movements to pull buckets of water out of the sea [16]. Since the creation of *Skyfarer*, another game called *Dash Lane* has been designed around shoulder exercises recommended for wheelchair users [33, 34]. Players drive along multi-lane tracks while shooting and switching lanes to avoid obstacles. Players raise their arms to shoot and punch to the left or right to switch lanes. Games such as *Skyfarer* and *Dash Lane* provide players a more enjoyable and compelling experience of performing shoulder exercises by transforming the player's physical activity into movement-based metaphors for gameplay activities [16].

2.3.3 Wheelchair & Arm Ergometry Games. GAME$^{\text{Wheels}}$ and GAME$^{\text{Cycle}}$ enable players to control digital games using their manual wheelchair or an arm ergometer [11, 12, 18, 41, 42, 51]. Players using GAME$^{\text{Wheels}}$ push their wheelchairs on metal rollers that keep them in place. The device uses the rotation speed of each wheel to drive movement in games such as *Need for Speed 2* [12]. GAME$^{\text{Cycle}}$ is used by cranking an ergometer's hand pedals and tilting the ergometer from side to side to turn. Playing games using these interfaces has been shown to produce physiological responses that are similar to or better than responses elicited by wheelchair or arm ergometry alone [11, 41, 43].

Figure 2: A woman with tetraplegia playing *Dino Dash* with a joystick and bite switch while passively cycling.

Other active games have proven effective in spinal cord injury rehabilitation. Active games have been shown to improve the physical capacity [7, 14, 25, 35, 36, 47, 49] and functional performance [13, 28, 30, 32, 52] of players with spinal cord injury. These findings led Mat Rosly et al. to conclude that active gaming can be considered to be at least as good as traditional exercise in a clinical setting [35].

While the clinical efficacy of these games is well understood, patients' *experiences* of playing rehabilitation games have been given less attention [31, 32]. Prior work has reported these games to be both fun and motivating [12, 18] and more fun than rehabilitation exercise alone [16, 36]. Players' enjoyment is influenced by the game's accessibility [31, 32]. Little is known, however, about patients' enjoyment of these games or how they fit into the broader context of rehabilitation. These prior works have investigated measures of usability and fun from an exclusively quantitative perspective. To the best of our knowledge, this is the first qualitative investigation dedicated to deep exploration of patients' experiences of rehabilitation gaming.

3 STUDY DESIGN

To explore whether accessible games can improve patients' experiences of spinal cord injury rehabilitation, we conducted a study in which six patients played three cycling-based rehabilitation games. During play, participants either *actively cycled*, meaning they pushed the pedals for themselves, or *passively cycled*, meaning that the device's motor moved their legs through range-of-motion exercise. After play, participants were interviewed to gather their impressions of rehabilitation and rehabilitation gaming. Participants' data were analyzed using thematic analysis [4–6] to answer our research question: *How can rehabilitation games affect patients' experiences of spinal cord injury rehabilitation*? In this section, we describe the games that participants played, the devices they used

to play, the recruitment and demographics of participants, the study procedure, and how the data were collected and analyzed.

3.1 Rehabilitation Games

Three rehabilitation games were used in this study: *Dino Dash*, *Dozo Quest* (both shown in Figure 3), and *MOTOmax* (Figure 4). The first two were taken from the *Liberi* suite of rehabilitation games. These games were originally designed for children with cerebral palsy who can pedal a bicycle and use a gamepad controller [20, 21]. Since patients with spinal cord injury may be unable to pedal a bicycle or use a gamepad, these games were adapted to make them accessible. The final game, called *MOTOmax*, is part of the MOTOmed viva2's software and was used as shipped. It is played by actively cycling on the viva2 and is therefore inaccessible to many patients in spinal cord injury rehabilitation. We now describe these games and how they are played.

3.1.1 Adaptive Play. For players who cannot actively cycle, the viva2 passively cycles for them during play, stimulating their leg muscles. In *Dino Dash* and *Dozo Quest*, if the player cycles passively, then game mechanics controlled by cycling are instead automated. However, in *MOTOmax* no gameplay assistance is provided for players who cannot pedal. In *Dino Dash* and *Dozo Quest*, players who cannot use the gamepad can instead control the analog stick and face button inputs with an *arcade-style joystick* or a *bite switch*—a button that is held in the mouth and activated by biting on it, as shown in Figure 2. If a player cannot use these devices either, then the mechanics they control are controlled via automation. We have called this accessibility technique *partial automation*, since it automates control of inaccessible parts of the game [9].

3.1.2 Dino Dash. In *Dino Dash*, the player controls a red dinosaur, called a Dino, that moves around an arena collecting eggs and bringing them back to its nest (Figure 3 left). The player competes against computer-controlled Dinos to be the first to collect ten eggs. The player controls the Dino's movement speed by pedalling the viva2 and uses the gamepad to control the Dino's movement direction with the left analog stick. When the player presses any of the gamepad's face buttons, the Dino shoots a projectile attack that momentarily stuns opponents and causes them to drop their eggs.

3.1.3 Dozo Quest. *Dozo Quest* is a platformer where the player controls a spiky red ball, called a Dozo, that rolls around, jumps, and does a dash attack that hurts enemies (Figure 3 right). The player wins the game by exploring a dungeon to find and defeat the final boss. As the player traverses the dungeon's maze-like chambers, they encounter dangerous traps to avoid and minor enemies to defeat. The Dozo's movement speed is controlled with the viva2 and its movement direction and the timing of its attack are controlled with the gamepad.

3.1.4 MOTOmax. *MOTOmax* is a cycling-based rehabilitation game provided with the viva2 (Figure 4). Players control a circular avatar that moves to the left or right side of the screen when the player is pedaling harder with their left or right leg respectively. These relative forces are shown on-screen to the player as the percentage of the pedalling force exerted by each leg. When the player exerts symmetric pedaling force, the avatar jumps up and down in the center of the screen, awarding the player points based on how fast they are pedalling. Although this game can be played while the viva2 passively pedals, the player's score will never increase. This is because the point of the game is to promote symmetric pedalling and passive cycling is inherently symmetric. *MOTOmax* was used in this study to provide a baseline for current commercial spinal cord injury rehabilitation games and to elicit participants' impressions of a rehabilitation game that is inaccessible to some persons with spinal cord injury.

3.2 Participants

Six participants with spinal cord injury were recruited, three of whom had tetraplegia and three paraplegia. A1 and A2 could actively cycle and P1-4 could use the viva2 through passive cycling. Participants were required to have spinal cord injury, be between 18 and 50 years old, have at least 50 hours of lifetime gaming experience, be in/outpatients at the hospital where sessions were conducted, and be able to participate in an interview. They were recruited by a spinal cord injury physiatrist and through a community-circulated poster. Participants' demographic data, including their AIS classifications and neurological levels of injury are shown in Table 1.

All participants had used a cycling device such as the viva2 in their rehabilitation, but none were aware of the *MOTOmax*, *Dino Dash*, or *Dozo Quest* games before their study session. Two participants said that their gaming habits had changed as a result of their injury. A2 had difficulty using gamepad controllers due to tetraplegia, which prevented him from playing his favorite first-person shooters, such as the *Call of Duty* games. P3 said that she played console games before her injury, but has since taken to playing computer games using a mouse, because she cannot use a gamepad. P1 and P4 said that they did more gaming in childhood and early adulthood, but also that spinal cord injury had not affected their gaming habits. Both A1 and P2 said that neither the games they played nor the frequency with which they played were affected by spinal cord injury, with P2 citing over eight-thousand hours of lifetime computer game play. Two participants also mentioned playing active games: P2 played active games, such as *Beat Saber* and *Subnautica*, in virtual reality and advocated their use in rehabilitation; P3 said that she was interested in playing active games, but found their interfaces disabling. Overall, participants were excited by the prospect of integrating games into rehabilitation.

3.3 Procedure

Upon arrival at the rehabilitation hospital gym where the sessions took place, each participant was guided through the informed consent procedure and completed a demographic questionnaire. The demographic questionnaire asked about their age, sex, injury classification, neurological level of injury, and gaming experience both before and after injury. Before playing each rehabilitation game, the participant's physical condition was assessed by hospital staff and they were asked for verbal confirmation that they felt fit to continue. Participants played *MOTOmax* first, then *Dino Dash*, and finally *Dozo Quest*, each for approximately ten minutes including

Figure 3: *Dino Dash* on the left and *Dozo Quest* on the right.

Table 1: Participants' demographic information. Participant IDs are coded according to whether they actively (A) or passively (P) cycled during play. AIS grades indicate whether their injury is complete, meaning no sensory or motor function was preserved at sacral segments S4-S5, or incomplete, meaning some sensory or motor function was retained. Neurological level of injury (NLI) specifies the part of the spinal cord that was injured. $GF_<$ and $GF_>$ denote participants' gaming frequency before and after injury respectively. The final column indicates whether participants actively or passively cycled during play.

Participant ID	Age	Sex	Years Injured	AIS Grade	Type of Paralysis	NLI	$GF_<$	$GF_>$	Cycling
A1	31	Male	< 1	Incomplete (C)	Paraplegia	T11	Monthly	Monthly	Active
A2	33	Male	5	Incomplete (B)	Tetraplegia	C4	Daily	Weekly	Active
P1	31	Male	< 1	Complete (A)	Paraplegia	T5	Weekly	Monthly	Passive
P2	23	Male	2	Complete (A)	Paraplegia	T4	Daily	Daily	Passive
P3	33	Female	15	Incomplete (B)	Tetraplegia	C5	Daily	Daily	Passive
P4	28	Male	9	Complete (A)	Tetraplegia	C4	Weekly	Monthly	Passive

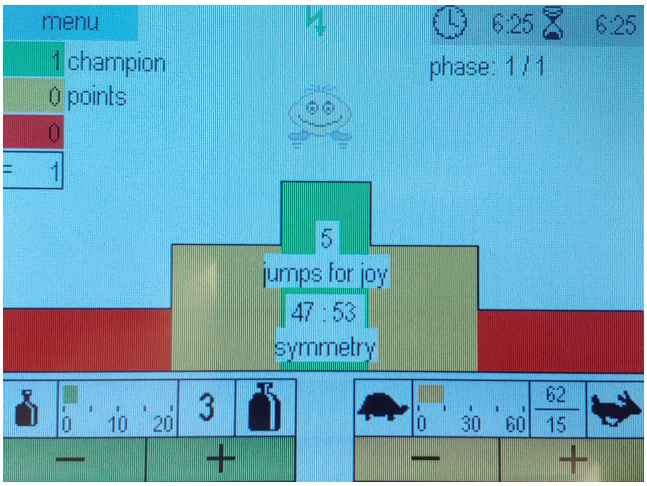

Figure 4: The *MOTOmax* game shipped with the viva2 rewards players for symmetric pedalling.

training time. After playing all of the games, participants were interviewed for approximately 30 minutes to capture their experiences of rehabilitation and of playing each game.

3.4 Data Collection & Analysis

Participants took part in semi-structured interviews about their experiences of rehabilitation and playing rehabilitation games. All interviews were conducted by the same researcher. Participants' sessions were video recorded and their post-gameplay interviews were both video and audio recorded. Interviews were transcribed manually by one researcher using the audio recordings, while video of participants speaking was used to verify the fidelity of transcriptions. These transcribed interviews formed the basis of our qualitative data. Video of participants' gameplay sessions were not transcribed in their entirety, but some portions of interest were transcribed and analyzed. For example, P3 commented on how similar the joystick she uses to drive her power wheelchair was to the joystick she used to play *Dino Dash* and *Dozo Quest*. When she tried it out, she said "*I should have no problem with this.*"

Participants' interviews were analyzed using reflexive thematic analysis [4–6]. Themes were developed inductively, with consideration for both the explicit semantic content and the latent semantics of participants' reported experiences, to capture the perspectives constructed by the data. The researcher who transcribed the interviews coded the data and developed the themes, which were reviewed by two others. Eight minor themes were identified and then reorganized into two major themes, one related to how participants experienced rehabilitation and the other related to how

gaming could change patients' experiences of rehabilitation. In the next section, we report the results of our analysis.

4 RESULTS

A spinal cord injury is both physically and psychologically traumatic. Participants cited feelings of hopelessness upon admission into rehabilitation, a belief that improving one's physical condition through exercise was futile, and a sense that the life they knew before injury was over. They each described how playing games as an inpatient would have improved their experiences of rehabilitation beyond making exercise more fun. Participants believed that rehabilitation gaming would have helped them to assess their physical abilities, monitor their progress, set goals, avoid depressing thoughts, find the motivation to exercise, and engage with peers. They described how games that are accessible to patients in spinal cord injury rehabilitation could guide them through this profoundly disruptive period in their lives. Participants frequently referenced their negative experiences of rehabilitation when explaining the potential benefits of gaming. To understand how games might change players' experiences of rehabilitation, we therefore need to appreciate the context of rehabilitation. In this section, we present two themes, called *the ordeal of spinal cord injury* and *from passive to active*, that illustrate how these patients experienced spinal cord injury rehabilitation and their views on how accessible games could help patients to overcome such an ordeal.

4.1 Theme: *The Ordeal of Spinal Cord Injury Rehabilitation*

Participants shared with us their experiences of grief, depression, hopelessness, disability, boredom, rumination, and anxiety in rehabilitation. They believed that gaming would have improved many of their negative rehabilitation experiences. This theme synthesizes three minor themes: *feeling like your life is over*, *left to your own devices*, and *time for reflection*.

4.1.1 Feeling like your life is over. Participants described an immense grief that they experienced following spinal cord injury. A2 and P4 explained that patients may feel that their lives were ended by their injuries. P4 said that "[Rehabilitation gaming would be beneficial] *for anyone who, I'd say, has had some sort of injury and thinks that life might be over, but there's still lots to do in life.*" Participants' accounts of these experiences revealed that patients may believe their injuries to have transformed them into a new person altogether. Disabled and alienated by the lives they knew, patients may struggle to adjust to their changed and alien bodies. A2 explained that "[A traumatic injury is] *a very depressing moment because you don't really want to talk to anyone. I became very combative because, well, one day I was fine and the next minute I'm a different person altogether physically.*" He believed that patients' grief could instill in them a demotivating depression that prevents them from speaking with others, coming to terms with their injury, and participating in rehabilitation. He said, "*There's a lot of people that don't* [participate in rehabilitation exercises] *and they just quit because 'My injury has done this to me. My life is over.' And that's a lot of where the depression comes from. And I get it; I had bad days as well.*"

4.1.2 Left to your own devices. Days come in different flavors in spinal cord injury rehabilitation. Days spent grieving are bad days, days filled with people to see and things to do are great days, and some days are slower days. P2 explained that "*A slower day would be where my main physiotherapist was busy with another patient and the* [occupational therapy/physiotherapy] *assistant I was with got busy with someone else as well. So, I was just left to do basic exercises.*" He said that he received less attention from hospital staff the closer he got to discharge. Being unable to pedal for himself, this left P2 with nothing to do while cycling. He said that "*Having something like* [*Dino Dash*] *would quickly pass the time.*" This sentiment was expressed by other participants who said that playing games would have alleviated the boredom of cycling.

P3 did her inpatient rehabilitation at an older hospital and lamented her lack of access to technologies to keep her entertained while cycling. Since she could not pedal the viva2 herself during rehabilitation, cycling represented a boring activity that left her with little to do. She said that "*You kind of were left to your own devices when you were working out. So, you could either interact with somebody else or you could just kinda sit there.*" Since she could not actively participate in the exercise, P3 did not find cycling to be adequately engaging. She said that "*A lot of times you, like, look out the window and you people watch... So, it's kind of hard to get like the motivation to want to go down to physiotherapy all the time when you're an inpatient, because sometimes it can be boring.*" For participants who could not pedal, it made no difference if they were actively participating in cycling. P1 shared his experience of using a motorized cycling device, saying that "*It's just boring and I'm just letting the machine do everything for me and just waiting until the time's up.*" With no way to get involved in cycling, participants who could not pedal were forced to kill time until it was over. P4 got his own viva2 after discharge, which he integrated into his daily routine. When asked what he does while using the device, he said "*I usually, like, sleep the whole time I'm on the* [viva2]." He explained that he saw no reason to stay awake while cycling; saying that "*For me, it is just more of a range-of-motion type exercise... It does all the work. I know I can't do any of the work myself because of my complete paralysis.*" P3 and P4 believed that the range-of-motion exercise afforded by a motorized cycling device, such as the viva2, provided them a necessary benefit. However, being unable to do the work themselves, participants who could not pedal had no way to participate in the exercise that was being done for them.

Participants who could pedal the viva2 mentioned the tedium of cycling as well. When asked how cycling was used in his rehabilitation, A1 said that he would cycle forwards for half an hour and then backwards for half an hour. He explained that "*It was boring just sitting there pushing the pedals. Yeah, for sure I would have* [preferred to play games while cycling]." A2 believed that rehabilitation exercise should be more interactive, citing a physiotherapy session in which he used rollerblades on a treadmill to simulate skating. He said that rehabilitation games, such as the three he played during his session, would have kept his mind occupied while cycling. He said, "*When I did it I was just listening to music or weirdly adding numbers in my head... But, doing something like this keeps your mind occupied while you're physically active, which is definitely a positive.*"

4.1.3 Time for reflection. When asked if he believed that gaming would make rehabilitation exercise more enjoyable, P1 said that it would because "*It keeps your mind off of other things.*" A1 responded similarly that "*Playing games takes your mind off other things.*" Overall, participants believed that a major benefit of gaming during rehabilitation exercise is that it distracts players from the "*other things*" that occupy their minds. The undesired thoughts that participants wanted to avoid were, of course, specific to each individual, but A2's account of his own rehabilitation experience illustrates how inpatients can take to rumination. He said,

> "*When I was in the rehab center, during the day it was great because there was so many people there and there's things to happen or things to do. At 5:30 or 6 o'clock, when everybody went home, it's the most depressing place in the goddamned world. And it is, because now it's when you're by yourself and it's 'Okay, I'm in a wheelchair. I can't stand up and walk to this door. I can't stand up and take my dog for a walk. Or do this. Or do that.' And that's a lot of time for reflection. And usually it's never positive. It's always a very depressing thing to watch, and it is.*"

Participants said that free time that was not mentally stimulating made them feel uncomfortable. Doing rehabilitation exercises that did not require their attention presented opportunities to dredge up undesired thoughts. P3 explained how she fills the mentally empty time she spends exercising: "*So, if I'm working out at home... working out on my arm bike and then I have music. I have to have, like, something. I have to have music, or I have to have the TV on.*" P3 explained that without adequate mental stimulation she could become anxious about stressors unrelated to exercise: "*There has to be something else, I just can't be doing one thing because then my brain just works too hard and it goes in... Like, I start thinking about all the things that I have to do and my anxiety starts piling up a little bit more.*" P4 believed that negative experiences of exercise could be particularly demotivating for "*young people*" newly admitted as inpatients, but that games involving rehabilitation exercises could help them to become more comfortable with physiotherapy. He said, "*I think it'd help people to be more inclined to do physiotherapy. Especially if they didn't want to do it or felt like it wasn't helping them in any way. At least this way, they can at least do physio and get some sort of other stimulation from it that might make them feel more comfortable with doing physio on a regular basis.*" Overall, participants believed that, beyond making exercise more fun, gaming could help patients to overcome their negative experiences of rehabilitation.

4.2 Theme: *From Passive to Active*

Playing games while cycling gave participants new ways to engage in rehabilitation exercises, made their efforts more meaningful and rewarding, and enabled them to actively participate in a previously disabling activity. However, participants' experiences of each game differed greatly depending on whether the game was accessible. *MOTOmax*, which was inaccessible to P1-4 because it required them to actively cycle, conferred benefits to A1 and A2 but not others. In contrast, all participants said that playing the universally accessible *Dino Dash* and *Dozo Quest* games would have improved their experiences of rehabilitation. The following minor themes recount how playing rehabilitation games improved participants' experiences of cycling rehabilitation therapy. The minor themes are: *gaming engages the whole body*, *gaming engages body and mind*, *gaming gives meaning to exercise*, *gaming lets you win at something*, and *gaming enables active participation in rehabilitation.*

4.2.1 Gaming engages the whole body. We began each interview by asking participants to compare playing rehabilitation games with their normal physiotherapy. For participants who could not pedal, the games gave them new ways to engage in cycling. P3 explained that playing *Dino Dash* and *Dozo Quest* put her mind at ease during an otherwise uncomfortably boring activity: "*I haven't got to work out my legs in a while. So, it was nice but it also gave me something to... I'm one of those people that I have what I have labelled 'idle hand syndrome'.*" She went on to say that "*It's more so in a sense that I can be doing something but if my brain isn't engaged, if I'm not busy doing something else... Like, I like to multitask a lot.*" She, and other participants, wanted something to do with their idle hands and minds while cycling.

P2 was particularly excited about the possibility of playing virtual reality (VR) games in physiotherapy. He explained how he plays a game called *Subnautica* that asks players to perform large arm movements to control the game's mechanics. He explained that "*If you play it in VR, you have to move your arms to do a swim motion... You can't get your legs moving if you're a paraplegic, like myself, but it gets your core muscles and upper-body going.*" He believed that VR games could improve rehabilitation for patients with paraplegia who could engage in gamified upper-body exercises, but not leg exercises. Conversely, A1 was able to pedal the viva2 and use the gamepad. When asked how *Dino Dash* could be made more enjoyable, he said that he might have preferred to play without the controller. He was especially invested in doing high quality exercise and believed that focusing on cycling would improve his workout. Therefore, he had reservations about using a gamepad while cycling, since it might diminish his quality of exercise. However, eventually he concluded, "*I guess the joysticks are better. Gets everything working: brain, hands, legs.*" Playing games while cycling offered participants a holistic means of participating in their exercise.

4.2.2 Gaming engages body and mind. Playing rehabilitation games gave participants something to focus on while cycling, which engaged not only their bodies but their minds as well. P3 said, "*It engages your brain as you're engaging your body as well and it doesn't really make it seem like working out. It makes it fun.*" She explained that gaming provided an interactivity that other forms of entertainment could not, saying that "*It was fun to actually focus on something other than like just listening to music, like my brain could actually interacting.*" A2 shared a similar sentiment, believing that distracting patients from boring exercises would be beneficial: "*If I had the ability to listen to music in that moment then I would. But, then you're still focusing on the exercise itself. It's a way, I think, having a game in front of you or a visual aid of some kind, especially if it's interactive with the exercise itself, would take your mind off the exercise itself completely.*" P4 saw the potential for rehabilitation games to engage patients in their exercise. He said that "*It definitely is a way for me to keep myself, like, engaged in actually what is going on and I think it is, for myself as someone who hasn't done a lot of*

gaming, it is an interesting way to engage people into their therapy sessions."

The games made doing the same repetitive and boring exercise more engaging by giving participants new virtual worlds and ways of playing to explore. P2 liked that playing *Dino Dash* required him to keep track of and reason about many game pieces. He said that "[Playing *Dino Dash*] *made my brain think like 'Okay, I've gotta focus on three other characters, I gotta focus on where the eggs are gonna spawn, where I gotta deliver them to, as well as my power level, and when I can attack.'*" A2 believed that this increased cognitive load could reframe rehabilitation exercises as a primarily mentally stimulating activity. He explained that "*You're not even thinking about the exercise you're getting and now you're training your brain as well. So, you can literally play that game for half an hour and not realize you just biked for half an hour. So, it doesn't even feel like exercise... Sure, there's exercise involved in it, but I'm not exercising, I'm playing a game. So, it's different. It's a different mindset.*"

Participants found playing games to be a welcome distraction from cycling, which could be mentally under-stimulating and induce rumination. Playing the games engendered a different mindset that helped participants to overcome the discomforting boredom, anxiety, and disability that they normally experience while cycling. For participants who cycle passively, play made them feel better about being unable to contribute to their exercise. However, games can only benefit patients when they are able to play. *MOTOmax* was inaccessible to P2, since he passively cycled during play, and therefore it did not hold his attention. He said that "[*MOTOmax*] *is the one that I liked the least, 'cause I had no way of actually doing anything... Because the game relied on you pedalling equally on both sides to complete it. I can't pedal.*" Disabled by the game, P2 said that being unable to play *MOTOmax* was frustrating and that the cycling was no different than normal. He spent this part of his session waiting for it to be over and thinking "*Can we just move on to the next, please?*"

4.2.3 Gaming gives meaning to exercise. Participants found that playing games was gratifying in ways that rehabilitation exercise was not. P4 believed that rehabilitation gaming could help patients to find the motivation to exercise. He said, "*some people might feel that it is a waste of time and not sure why they're doing it... So, I think it just allows them to have another objective to why they are doing physio.*" Participants who could not pedal believed that patients would be motivated to exercise if they made overcoming the games' challenges a rehabilitation goal. P3 explained that "[Gaming would be motivating] *just because it would give you something to look forward to... Then if there is more levels, then obviously people will want to keep coming back to play more levels to see how far that they can get.*" Although patients' achievements in the games may be unrelated to the exercise they are doing, participants who could not pedal believed that gameplay related rehabilitation goals would compel patients to exercise and would make their efforts more meaningful.

A1 and A2 believed that patients who could pedal would also be motivated by exercise-related gameplay goals. A2 proposed that a fake scoreboard be added to *MOTOmax*. He told us to "*Make the top score slightly under* [the player's best] *so that whenever anybody's doing it they can feel that more of a sense of accomplishment. Because otherwise the number you get at the end is meaningless without merit. Like, so great, I got an 82. Is that normal? Is that above average? Below average? If you gave it meaning to the player I think that would make it more enjoyable to them. 'I have to beat this number.'*" He believed that feedback from *MOTOmax* would enable competitions between patients in rehabilitation, motivating them to work harder. A1 found an immediate benefit to *MOTOmax*'s feedback. He said that "*It'd be a goal... Like while you're on it, just to see and check both legs... What leg's stronger, what leg's weaker. You're pushing to keep it in the middle.*" During play, the game informed him of how hard he was pedalling with each leg. This provided him with immediate feedback, which A2 said was sorely lacking in rehabilitation. He said that "*It's just more feedback immediately rather than waiting for a doctor to say this or that. You'd automatically see how you're doing.*" He believed that feedback from *MOTOmax* would be a valuable tool for patients to track their progress over time, motivating them to "*every day do better.*"

Participants believed that rehabilitation gaming would motivate patients to exercise, but only if the games were accessible. When asked if she believed that playing *MOTOmax* would make physiotherapy more enjoyable, P3, who passively cycled during play, said "*I don't think I could really give an opinion on it because it didn't work for me. So, I don't know how the game is supposed to work, but if someone has like a little bit of, you know, ability to move their legs it might definitely help them in encouraging them to do more possibly. Because they can see how much they're like contributing to the game.*" *MOTOmax*'s exercise performance feedback benefits players who can pedal at the expense of players who cannot. The feedback that A1 and A2 found so useful served only to reconfirm for P1 that he was disabled by active cycling. When we discussed *MOTOmax* he said, "*I was just watching to see if I was actually pedalling at all. So, I was just concentrating on if I was doing anything, which I wasn't.*"

4.2.4 Gaming lets you win at something. When asked if any significant moments occurred while playing *Dino Dash* and *Dozo Quest*, participants often cited their victories. Competing against AI-controlled enemies and winning the games was thrilling in ways that cycling was not and gave participants "*a little bit of a sense of accomplishment*", as P3 put it. P2 said that "*It was sort of putting on tension and a rush like 'Okay, now I gotta beat this guy. I can't lose.'*" The games' challenges gave players obstacles to overcome and made them better players as they gained more experience. Becoming more competent players and beating more challenging opponents validated participants efforts. P2 recounted how this made him feel while playing *Dino Dash*, "*I was actively seeing progression, myself getting better and better. Winning like that felt good.*" For participants who could not actively pedal the viva2, gaming offered them a chance at victory, which cycling could not.

The opportunity to win is what P1 liked best about *Dino Dash*. He said, "*It was a lot of fun... Just 'cause it was like a race... Like, how you can win at something... Puts a little competition into it.*" A2, as well, found the game's competitive nature compelling and believed that competitions between patients would motivate them to exercise. He said "*Something like this would be great just to socialize you with your other patients, other people, and just get you going again, and give you a competitive fire again, and maybe make you want to work harder.*" He believed that social interactions with competitors

would enable patients to help each other cope with feelings of hopelessness. He explained that "[Patients become] *upset when somebody is just giving up. Like I yelled at a bunch of people in physio because they would just quit and something like this where you could literally stack up against everybody* [would be motivating.]" A2 also saw opportunities for clinicians to leverage patients' envy of each others' abilities to drive competition. He said, "*The one thing that a lot of the doctors and physios don't take into account is the human aspect. The fact that each patient is looking at every other patient as well and wishing 'Oh, they can do this; so, I wish I could do this. They can do that; I wish I could do that.'*" He believed that playing *Dino Dash* against other patients would have motivated him to spend more time exercising as an inpatient. He said that "*I would have been on that thing every free moment I had, after all my therapies and whatever, I would have been going to Dino Dash. Gonna kick some ass!*"

4.2.5 Gaming enables active participation in rehabilitation. Participants who could not pedal the viva2 believed that they were not participating in cycling, since the device's motor moved their legs for them. P1 described how this made him feel and explained how playing the games made him feel better. He said, "*If it's just passively pedalling then I feel like I'm not really doing anything. So, if you have something else there on the same, you know, device, it makes you feel like a little better about using it.*" For these participants, cycling represented an activity that they needed to do, despite their inability to actively participate in the exercise. When asked what he liked about *Dino Dash*, P4 said that it gave him something to do while cycling. He said, "[It was engaging] *just being able to... play a game while you're there, instead of just sitting there and staring at a wall.*" The games not only alleviated participants' boredom while cycling, it enabled them to participate in a previously disabling activity. When describing what he liked about playing games while cycling, P1 said that "*There's a little more to do than just go through the motions of physio.*"

Participants only reported feelings of increased participation when playing games that were accessible to them. A1, who pedalled the viva2 while playing *MOTOmax*, said that it made cycling more engaging because "*You have a goal of keeping that guy in the middle. Keeping both legs at 50% and just not staring off into the world, doing nothing.*" However, P3 was unable to play *MOTOmax* and believed that, just like her normal cycling-based exercise, she "*Totally wasn't contributing to* [*MOTOmax*] *at all.*" For participants who could not play *MOTOmax*, the game offered no benefit. As P2 put it, "*To me* [playing *MOTOmax*] *was just going back to regular exercise. It wasn't really pulling me in.*"

5 DISCUSSION

We have reported the experiences of six patients at a local rehabilitation hospital playing three rehabilitation games. Participants told us that playing games might have alleviated the depression and anxiety they experienced going through rehabilitation and adjusting to life with spinal cord injury. They said that a spinal cord injury can leave patients feeling depressed, alienated, and hopeless. They found exercises, particularly when performed passively, to be boring, demotivating, and disabling. They said that boring activities, such as passive cycling, could induce ruminations that stir up negative emotions, offering patients opportunities to reopen fresh psychological wounds. In contrast, playing rehabilitation games enabled participants to actively participate in a previously passive and disabling activity. Gaming gave participants new ways to engage with cycling by providing them something to do with their idle hands and minds. Playing the games and overcoming their challenges was exhilarating in ways that going through the motions of physiotherapy was not. This made exercise more meaningful and enabled participants to set goals for themselves, either in terms of their exercise performance or gameplay performance. Achieving these goals made participants feel accomplished, regardless of whether they actively cycled, and might have motivated them to work even harder in their own inpatient rehabilitation.

This is not the paper we planned to write when we designed this study. We thought that addressing the boredom of rehabilitation exercise, described in Section 2.3, was the primary way in which games could improve patients' experiences of rehabilitation. Since it is difficult to design rehabilitation games that can be played by people with radically different abilities, such as among patients with spinal cord injury, we wanted to see how playing accessible and inaccessible games changed participants' experiences of rehabilitation exercises. But after reflecting on participants' reported experiences, it became apparent that the fun and motivation that rehabilitation gaming affords was only a small part of the stories participants had to tell. Their responses to questions such as "*Did playing the game make you focus on using the* [viva2]" were far more detailed and introspective than we anticipated. While participants did find play more compelling than their normal exercise, evidently this was not the only way that play was meaningful to them. Their accounts of how rehabilitation made them feel and how playing games, in physiotherapy or for leisure, might have made these experiences better indicate that rehabilitation games may provide patients benefits beyond making exercise more fun. We consider this initial investigation to be a conversation starter. Our analysis can only comment on how rehabilitation gaming affected the experiences of these participants and further investigation would be needed to determine if these effects are experienced by others. In the rest of this section, we explore how our findings compare with prior knowledge and describe how patients' experiences of rehabilitation gaming for spinal cord injury might be investigated further.

The potential benefits of gaming in spinal cord injury rehabilitation, as described by participants and identified in our analysis, have some correspondence with the three psychological needs of self-determination theory. These are *autonomy*, *competence*, and *relatedness* [10]. Participants' reported experiences suggest that playing games in rehabilitation may support patients' intrinsic motivation to engage in rehabilitation activities. They said that play enabled them to actively participate in their exercise, supporting their autonomy; that play gave them goals to achieve and positive feedback, supporting competence; and that competition with others could help patients to socialize with peers, supporting relatedness. These potential benefits highlight the fact that patients' physiotherapy happens in the wider context of rehabilitation, which can be alienating and disabling. It may be that self-determination theory provides a wider lens through which the context of rehabilitation can inform the design of rehabilitation games, which Kaos et al.

argue can improve the effectiveness of gamified interventions [44]. In this section, we ground our results in the literature, comparing insights drawn from our analysis with patients' experiences of rehabilitation reported elsewhere.

5.1 Autonomy: Involving Patients in Their Rehabilitation

Participants reported a demotivating lack of engagement while passive cycling without playing games. P4, who often sleeps during passive cycling, believed that it did not matter whether he actively participated in the activity. This could be a significant downside of passive range-of-motion exercises because, as explained by Lindberg et al., patients who actively participate in their rehabilitation are more adherent to treatment, achieve better outcomes, and are more satisfied with rehabilitation [29]. Participants' statements illustrate how rehabilitation games can engage players in exercise regardless of whether the exercise is performed actively or passively. Players who exercise actively may find play distracting and prefer to focus on the exercise, as mentioned by A1 who said he might have preferred to play using only the viva2, however games can also provide feedback that makes their efforts more meaningful. Overall, playing games gave participants something to do while cycling, which they said could be mentally under-stimulating. Both Hammell and Chun & Lee reported that patients may find periods of free time, such as evenings and weekends when rehabilitation services are closed, distressing because they present opportunities to ruminate, which could be psychologically harmful [8, 53]. Participants' accounts of rumination during their inpatient rehabilitation and how playing games might have distracted them from the "*other things*" that occupied their minds reconfirms this observation. Participants suggested that playing rehabilitation games may help patients to temporarily escape psychological stressors that are out of their control. Playing games while passively cycling enabled players to actively participate and may confer a greater sense of involvement in their rehabilitation.

Both Lindberg et al. and Bourke et al. found that patients need to acquire and make sense of a lot of information regarding their injuries [3, 29]. Patients need to learn about not only the spinal cord, AIS classifications, and the long-term health risks of spinal cord injury but also which activities are now accessible or inaccessible to them. Understanding the consequences of spinal cord injury can enable patients to make decisions about their treatment for themselves, something that Bourke et al. found helped patients to regain control of their lives and rediscover their identities [3]. Playing games gave participants valuable feedback and a sense of accomplishment that they believed would motivate them to engage in rehabilitation exercises. Participants said that rehabilitation games would have compelled them to play, during physiotherapy or for leisure, and that the games made exercise feel like something they wanted to do, rather than something that was prescribed.

Participants said that playing games while exercising fostered a different mindset than their normal exercise and that the games gave them more to do than just go through the motions of physiotherapy. It may be that games can engender in patients an autonomous, rather than controlled or impersonal, causality orientation [10]. Given participants' accounts of people watching or napping during exercise, the increased sense of autonomy that gaming affords may significantly improve patients' experiences of physiotherapy and may enable them to apply this attitude towards other aspects of their rehabilitation. Bourke et al. found that patients need to feel in control of their rehabilitation to overcome the biographical disruption caused by spinal cord injury [3], so play may help patients to rediscover who they are. Our results hint that rehabilitation games can increase patients' experiences of autonomy and independence. Further investigation is warranted to determine how games and other technologies can improve patients' autonomy.

5.2 Competence: Showing Patients That "There's Still Lots to Do in Life"

When we asked P4 his opinion of playing games in rehabilitation, he said that they would be particularly effective at showing patients that they can still participate in activities after injury. Being able to play games may help patients to envision a better future for themselves, which Hammell found enabled patients to cope with the challenges of living with spinal cord injury [53]. Chun & Lee found that patients who see injury as a challenge to overcome are more likely to experience personal growth as a result of trauma [8]. P4's remark suggests that playing games may help patients realize an attitude that supports a generalized sense of competence. Participants said that they were driven to win the games and A2 said that play could help patients get back their "*competitive fire.*" It may be that striving for success and achievement in rehabilitation games can be one small part of patients adopting an energetic attitude towards the challenges of living with spinal cord injury.

Participants said that playing games made rehabilitation exercise more fun and that winning the games made them feel accomplished. Chun & Lee found that activities that engender positive emotions in patients can show them that a life with spinal cord injury is still worth living [8]. Patients who engaged in leisure activities were more confident in their abilities and became curious about other activities they could participate in. Other researchers, who investigated the potential benefits of active games, have also suggested that games can make physical activity more accessible to persons with disabilities [48] and stimulate their interest in other forms of physical activity [32, 54]. Participants in our study said that they were compelled to beat their opponents in *Dino Dash* and explore the dungeon in *Dozo Quest*. It may be that rehabilitation games can provide patients an accessible activity that leads them to explore, master, and enjoy other forms of playful physical activity.

Playing games may give patients a sense of competence that they can apply in other aspects of their lives. Discovering activities that they can participate in and overcoming challenges can help patients to restore their personal narrative [3] and reconnect their past to their future [53]. For some patients, gaming may be a beloved pastime that is no longer accessible to them. This was the case for A2 and P3, both of whom could no longer play console games because they found using a gamepad too difficult. For these patients, play may help them take back something that they lost. A2 described what playing rehabilitation games meant to him, saying that "[Playing rehabilitation games is] *not only, at that point, healing the body but it's also healing the mind. It allows you to think that you*

can still do something that, to be honest, you never thought that you'd be able to do again. You play video games, you can do something other than what you see when you go into a gym. So, that was great!" Rehabilitation games that are accessible to patients with spinal cord injury can show them that activities they enjoyed before may still be accessible to them.

5.3 Relatedness: Cultivating Relationships Among Peers

As mentioned in Section 5.1, patients need to make sense of the consequences of injury in ways that are meaningful to them. Bourke et al. and Lindberg et al. emphasized the role that peers play in patients' understanding of what living with spinal cord injury means [3, 29]. Peers can motivate patients to continue participating in rehabilitation and can show patients that the challenges they encounter can be overcome. A2 suggested that competitive rehabilitation games could foster these sorts of relationships among patients. He said that patients' desire to outperform others could motivate them to work harder in their own rehabilitation. Chun & Lee found that patients used leisure activities in a clinical setting to make connections with others [8]. Playing games together could provide patients with common ground in which to compare their abilities and experiences. Socializing with peers may be important for adjusting to life with spinal cord injury, since Chun & Lee found that patients who did not socialize with peers were less likely to experience personal growth [8]. It may be that communal gaming for leisure could help patients exhibiting anti-social behaviour, of the kind alluded to by A2 when describing patients' depression, to form meaningful relationships that inform and enrich their lives.

A sense of belonging to an organization, such as a play group or a rehabilitation cohort, has a tight correspondence with feelings of relatedness, which are necessary for intrinsic motivation [10]. Prior work has found that patients leverage strong social bonds with peers to cope with psychological trauma [3, 8, 29, 53] and also that players' adherence to active gaming regimens and sense of belonging is improved when they play together [26]. It may be that playing rehabilitation games together enables patients to encourage each other in an autonomy and competence supporting manner. Playing games together in clinic could foster a community of mutual support that extends beyond inpatient rehabilitation.

6 LIMITATIONS

Due to the major time and logistical effort required of participants with spinal cord injury to participate in studies such as this, our sample size was small (n=6) with only one female participant. While we are the first to focus on experiences in rehabilitation gaming, our results were consistent with previous studies of patients' experiences in other contexts, providing some confidence in their validity. However, follow-up studies with more and different participants are called for. Participants played each game for approximately ten minutes (including training time), which was sufficient to learn and experience these fairly simple games. However, longitudinal studies would be needed to capture participants' longer-term experiences.

7 CONCLUSION

Rehabilitation games have the potential to make exercise more fun and motivating for patients receiving rehabilitation after a spinal cord injury. These games can increase engagement in exercises that patients consider boring, and have been shown to be similarly or more effective than traditional exercise. To determine how games can change patients' experiences of rehabilitation, we conducted a study with six patients with spinal cord injury who played three rehabilitation games. Participants' accounts of rehabilitation indicate that a spinal cord injury can cause psychological trauma that games can help them to overcome. The potential benefits of rehabilitation gaming that participants described indicate that self-determination theory provides a lens through which patients' experiences of rehabilitation can be understood and improved. Participants believed that games could provide patients new ways to actively participate in their rehabilitation, avoid discomforting thoughts, and make their efforts more meaningful. Rehabilitation games may help to guide patients through the ordeal of spinal cord injury rehabilitation, conferring benefits beyond making exercise more fun.

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REFERENCES

[1] A.L. Betker, T. Szturm, and Z. Moussavi. 2005. Development of an Interactive Motivating Tool for Rehabilitation Movements. In *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference*. 6893–6896. https://doi.org/10.1109/IEMBS.2005.1616090 ISSN: 1558-4615.

[2] Aimee L Betker, Ankur Desai, Cristabel Nett, Naaz Kapadia, and Tony Szturm. 2007. Game-based Exercises for Dynamic Short-Sitting Balance Rehabilitation of People With Chronic Spinal Cord and Traumatic Brain Injuries. *Physical Therapy* 87, 10 (Oct. 2007), 1389–1398. https://doi.org/10.2522/ptj.20060229

[3] John A. Bourke, E. Jean C. Hay-Smith, Deborah L. Snell, and Gerben DeJong. 2015. Attending to biographical disruption: the experience of rehabilitation following tetraplegia due to spinal cord injury. *Disability and Rehabilitation* 37, 4 (Feb. 2015), 296–303. https://doi.org/10.3109/09638288.2014.918188 Publisher: Taylor & Francis _eprint: https://doi.org/10.3109/09638288.2014.918188.

[4] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (Jan. 2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[5] Virginia Braun and Victoria Clarke. 2013. *Successful qualitative research: a practical guide for beginners*. SAGE, Los Angeles. OCLC: ocn811733656.

[6] Virginia Braun and Victoria Clarke. 2019. Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health* 11, 4 (Aug. 2019), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

[7] Patricia Burns, Jochen Kressler, and Mark S. Nash. 2012. Physiological Responses to Exergaming After Spinal Cord Injury. *Topics in Spinal Cord Injury Rehabilitation* 18, 4 (2012), 331–339. https://doi.org/10.1310/sci1804-331

[8] Sanghee Chun and Youngkhill Lee. 2010. The Role of Leisure in the Experience of Posttraumatic Growth for People with Spinal Cord Injury. *Journal of Leisure Research* 42, 3 (Sept. 2010), 393–415. https://doi.org/10.1080/00222216.2010.11950211 Publisher: Routledge _eprint: https://doi.org/10.1080/00222216.2010.11950211.

[9] Gabriele Cimolino, Sussan Askari, and T.C. Nicholas Graham. 2021. The Role of Partial Automation in Increasing the Accessibility of Digital Games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '21)*. ACM, New York, NY, USA.

[10] Edward L. Deci and Richard M. Ryan. 2012. Self-Determination Theory. In *Handbook of Theories of Social Psychology: Volume 1*. SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom, 416–437. https://doi.org/10.4135/9781446249215.n21

[11] Shirley G. Fitzgerald, Rory A. Cooper, Tricia Thorman, Rosemarie Cooper, SongFeng Guo, and Michael L. Boninger. 2004. The Gamecycle Exercise System:

Comparison With Standard Ergometry. *The Journal of Spinal Cord Medicine* 27, 5 (Jan. 2004), 453–459. https://doi.org/10.1080/10790268.2004.11752237

[12] Shirley G. Fitzgerald, Rory A. Cooper, Emily Zipfel, Donald M. Spaeth, Jeremy Puhlman, Annmarie Kelleher, Rosemarie Cooper, and Songfeng Guo. 2006. The development and preliminary evaluation of a training device for wheelchair users: The GAMEWheels system. *Disability and Rehabilitation: Assistive Technology* 1, 1-2 (Jan. 2006), 129–139. https://doi.org/10.1080/09638280500167639

[13] Gabriella Fizzotti, Carla Rognoni, Arianna Imarisio, Alessandro Meneghini, Caterina Pistarini, and Silvana Quaglini. 2015. Tablet Technology for Rehabilitation after Spinal Cord Injury: a Proof-of-Concept. *Studies in Health Technology and Informatics* 210 (2015), 479–483. https://doi.org/10.3233/978-1-61499-512-8-479

[14] P. Gaffurini, L. Bissolotti, S. Calza, C. Calabretto, C. Orizio, and M. Gobbo. 2013. Energy metabolism during activity-promoting video games practice in subjects with spinal cord injury: evidences for health promotion. *European Journal of Physical and Rehabilitation Medicine* 49, 1 (Feb. 2013), 23–29.

[15] Marientina Gotsis, Fotos Frangoudes, Vangelis Lympouridis, Somboon Maneekobkunwong, David Turpin, and Maryalice Jordan-Marsh. 2013. Skyfarer: a mixed reality shoulder exercise game. In *ACM SIGGRAPH 2013 Studio Talks on - SIGGRAPH '13*. ACM Press, Anaheim, California, 1–1. https://doi.org/10.1145/2503673.2503675

[16] Marientina Gotsis, Vangelis Lympouridis, Phil Requejo, Lisa L. Haubert, Irina C. Poulos, Fotos Frangoudes, David Turpin, and Maryalice Jordan-Marsh. 2014. Skyfarer: Design Case Study of a Mixed Reality Rehabilitation Video Game. In *International Conference of Design, User Experience, and Usability*. Springer, 699–710. https://doi.org/10.1007/978-3-319-07626-3_66

[17] Marientina Gotsis, Amanda Tasse, Maximilian Swider, Vangelis Lympouridis, Irina C. Poulos, Alasdair G. Thin, David Turpin, Diane Tucker, and Maryalice Jordan-Marsh. 2012. Mixed reality game prototypes for upper body exercise and rehabilitation. In *2012 IEEE Virtual Reality Workshops (VRW)*. 181–182. https://doi.org/10.1109/VR.2012.6180940 ISSN: 1087-8270.

[18] Songfeng Guo, G.G. Grindle, E.L. Authier, R.A. Cooper, S.G. Fitzgerald, A. Kelleher, and R. Cooper. 2006. Development and qualitative assessment of the GAME/sup Cycle/ exercise system. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 14, 1 (March 2006), 83–90. https://doi.org/10.1109/TNSRE.2006.870493

[19] E. T. Harness, N. Yozbatiran, and S. C. Cramer. 2008. Effects of intense exercise in chronic spinal cord injury. *Spinal Cord* 46, 11 (Nov. 2008), 733–737. https://doi.org/10.1038/sc.2008.56 Number: 11 Publisher: Nature Publishing Group.

[20] Hamilton A. Hernandez, T.C. Nicholas Graham, Darcy Fehlings, Lauren Switzer, Zi Ye, Quentin Bellay, Md Ameer Hamza, Cheryl Savery, and Tadeusz Stach. 2012. Design of an Exergaming Station for Children with Cerebral Palsy. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 2619–2628. https://doi.org/10.1145/2207676.2208652

[21] Hamilton A. Hernandez, Zi Ye, T.C. Nicholas Graham, Darcy Fehlings, and Lauren Switzer. 2013. Designing Action-based Exergames for Children with Cerebral Palsy. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 1261–1270. https://doi.org/10.1145/2470654.2466164

[22] A. L. Hicks, K. A. Martin Ginis, C. A. Pelletier, D. S. Ditor, B. Foulon, and D. L. Wolfe. 2011. The effects of exercise training on physical capacity, strength, body composition and functional performance among adults with spinal cord injury: a systematic review. *Spinal Cord* 49, 11 (Nov. 2011), 1103–1127. https://doi.org/10.1038/sc.2011.62

[23] Kieran Hicks and Kathrin Gerling. 2015. Exploring Casual Exergames with Kids Using Wheelchairs. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '15)*. Association for Computing Machinery, London, United Kingdom, 541–546. https://doi.org/10.1145/2793107.2810304

[24] Patrick L. Jacobs and Mark S. Nash. 2004. Exercise Recommendations for Individuals with Spinal Cord Injury. *Sports Medicine* 34, 11 (Sept. 2004), 727–751. https://doi.org/10.2165/00007256-200434110-00003

[25] Jeffrey P. Jaramillo, M. Elise Johanson, and B. Jenny Kiratli. 2019. Upper limb muscle activation during sports video gaming of persons with spinal cord injury. *The Journal of Spinal Cord Medicine* 42, 1 (Jan. 2019), 77–85. https://doi.org/10.1080/10790268.2018.1452391

[26] Maximus D. Kaos, Ryan E. Rhodes, Perttu Hämäläinen, and T.C. Nicholas Graham. 2019. Social Play in an Exergame: How the Need to Belong Predicts Adherence. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300660

[27] Steven C. Kirshblum, Stephen P. Burns, Fin Biering-Sorensen, William Donovan, Daniel E. Graves, Amitabh Jha, Mark Johansen, Linda Jones, Andrei Krassioukov, MJ Mulcahey, Mary Schmidt-Read, and William Waring. 2011. International standards for neurological classification of spinal cord injury (Revised 2011). *The Journal of Spinal Cord Medicine* 34, 6 (Nov. 2011), 535–546. https://doi.org/10.1179/204577211X13207446293695

[28] Rachel Kizony, Liat Raz, Noomi Katz, Harold Weingarden, and Patrice L. Tamar Weiss. 2005. Video-capture virtual reality system for patients with paraplegic spinal cord injury. *The Journal of Rehabilitation Research and Development* 42, 5 (2005), 595. https://doi.org/10.1682/JRRD.2005.01.0023

[29] J. Lindberg, M. Kreuter, C. Taft, and L.-O. Person. 2013. Patient participation in care and rehabilitation from the perspective of patients with spinal cord injury. *Spinal Cord* 51, 11 (Nov. 2013), 834–837. https://doi.org/10.1038/sc.2013.97 Number: 11 Publisher: Nature Publishing Group.

[30] Laurie A Malone, Sangeetha Padalabalanarayanan, Justin McCroskey, and Mohanraj Thirumalai. 2017. Assessment of Active Video Gaming Using Adapted Controllers by Individuals With Physical Disabilities: A Protocol. *JMIR Research Protocols* 6, 6 (June 2017), e116. https://doi.org/10.2196/resprot.7621

[31] Laurie A. Malone, Jennifer L. Rowland, Rebecca Rogers, Tapan Mehta, Sangeetha Padalabalanarayanan, Mohanraj Thirumalai, and James H. Rimmer. 2016. Active Videogaming in Youth with Physical Disability: Gameplay and Enjoyment. *Games for Health Journal* 5, 5 (Oct. 2016), 333–341. https://doi.org/10.1089/g4h.2015.0105

[32] Laurie A Malone, Mohanraj Thirumalai, Sangeetha Padalabalanarayanan, Whitney N Neal, Sean Bowman, and Tapan Mehta. 2019. Energy Expenditure and Enjoyment During Active Video Gaming Using an Adapted Wii Fit Balance Board in Adults with Physical Disabilities: Observational Study. *JMIR Serious Games* 7, 1 (Feb. 2019), e11326. https://doi.org/10.2196/11326

[33] Liam Mason, Kathrin Gerling, Patrick Dickinson, and Jussi Holopainen. 2020. Dash Lane: An Adaptive Exergame for People Using Manual Wheelchairs. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference (DIS' 20 Companion)*. Association for Computing Machinery, Eindhoven, Netherlands, 321–324. https://doi.org/10.1145/3393914.3395823

[34] Liam Mason, Kathrin Gerling, Patrick Dickinson, and Jussi Holopainen. 2020. Dash Lane Mobile: Exploring Hypercasual Play to Provide Accessible Physically Active Breaks. In *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '20)*. Association for Computing Machinery, New York, NY, USA, 311–315. https://doi.org/10.1145/3383668.3419869

[35] Maziah Mat Rosly, Mark Halaki, Hadi Mat Rosly, Victor Cuesta, Nazirah Hasnan, Glen M. Davis, and Ruby Husain. 2017. Exergaming for Individuals with Spinal Cord Injury: A Pilot Study. *Games for Health Journal* 6, 5 (Oct. 2017), 279–289. https://doi.org/10.1089/g4h.2017.0028

[36] Maziah Mat Rosly, Hadi Mat Rosly, Nazirah Hasnan, Glen M. Davis, and Ruby Husain. 2017. Exergaming boxing versus heavy-bag boxing: are these equipotent for individuals with spinal cord injury? *European Journal of Physical and Rehabilitation Medicine* 53, 4 (Aug. 2017), 527–534. https://doi.org/10.23736/S1973-9087.17.04456-2

[37] Maziah Mat Rosly, Hadi Mat Rosly, Glen M. Davis OAM, Ruby Husain, and Nazirah Hasnan. 2017. Exergaming for individuals with neurological disability: a systematic review. *Disability and Rehabilitation* 39, 8 (April 2017), 727–735. https://doi.org/10.3109/09638288.2016.1161086

[38] Maziah Mat Rosly, Hadi Mat Rosly, Glen M. Davis OAM, Ruby Husain, and Nazirah Hasnan. 2017. Exergaming for individuals with neurological disability: a systematic review. *Disability and Rehabilitation* 39, 8 (April 2017), 727–735. https://doi.org/10.3109/09638288.2016.1161086

[39] Sara J. Mulroy, Lilli Thompson, Bryan Kemp, Patricia Pate Hatchett, Craig J. Newsam, Dee Gutierrez Lupold, Lisa Lighthall Haubert, Valerie Eberly, Ting-Ting Ge, Stanley P. Azen, Carolee J. Winstein, James Gordon, and Physical Therapy Clinical Research Network (PTClinResNet). 2011. Strengthening and optimal movements for painful shoulders (STOMPS) in chronic spinal cord injury: a randomized controlled trial. *Physical Therapy* 91, 3 (March 2011), 305–324. https://doi.org/10.2522/ptj.20100182

[40] Kemal Nas, Levent Yazmalar, Volkan Şah, Abdulkadir Aydın, and Kadriye Öneş. 2015. Rehabilitation of spinal cord injuries. *World Journal of Orthopedics* 6, 1 (Jan. 2015), 8–16. https://doi.org/10.5312/wjo.v6.i1.8

[41] Thomas J. O'Connor, Rory A. Cooper, Shirley G. Fitzgerald, Michael J. Dvorznak, Michael L. Boninger, David P. VanSickle, and Lisa Glass. 2000. Evaluation of a Manual Wheelchair Interface to Computer Games. *Neurorehabilitation and Neural Repair* 14, 1 (March 2000), 21–31. https://doi.org/10.1177/154596830001400103

[42] Thomas J O'Connor, Shirley G Fitzgerald, Rory A Cooper, Tricia A Thorman, and Michael L Boninger. 2001. Does computer game play aid in motivation of exercise and increase metabolic activity during wheelchair ergometry? *Medical Engineering & Physics* 23, 4 (May 2001), 267–273. https://doi.org/10.1016/S1350-4533(01)00046-7

[43] Thomas J. O'Connor, Shirley G. Fitzgerald, Rory A. Cooper, Tricia A. Thorman, and Michael L. Boninger. 2002. Kinetic and physiological analysis of the GAME(Wheels) system. *Journal of Rehabilitation Research and Development* 39, 6 (Dec. 2002), 627–634.

[44] Chad Richards, Craig W. Thompson, and Nicholas Graham. 2014. Beyond designing for motivation: the importance of context in gamification. In *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play (CHI PLAY '14)*. Association for Computing Machinery, New York, NY, USA, 217–226. https://doi.org/10.1145/2658537.2658683

[45] James H Rimmer, Barth Riley, Edward Wang, Amy Rauworth, and Janine Jurkowski. 2004. Physical activity participation among persons with disabilities: Barriers and facilitators. *American Journal of Preventive Medicine* 26, 5 (June 2004), 419–425. https://doi.org/10.1016/j.amepre.2004.02.002

[46] Timothy T. Roberts, Garrett R. Leonard, and Daniel J. Cepela. 2017. Classifications In Brief: American Spinal Injury Association (ASIA) Impairment Scale. *Clinical Orthopaedics and Related Research* 475, 5 (May 2017), 1499–1504. https://doi.org/10.1007/s11999-016-5133-4

[47] Sharmella Roopchand-Martin, Gail Nelson, and Carron Gordon. 2014. Can persons with paraplegia obtain training heart rates when boxing on the Nintendo Wii?(CASE STUDY)(Author abstract). *New Zealand Journal of Physiotherapy* 42, 1 (March 2014), 28–32.

[48] Jennifer L. Rowland, Laurie A. Malone, Cali M. Fidopiastis, Sangeetha Padalabalanarayanan, Mohanraj Thirumalai, and James H. Rimmer. 2016. Perspectives on Active Video Gaming as a New Frontier in Accessible Physical Activity for Youth With Physical Disabilities. *Physical Therapy* 96, 4 (April 2016), 521–532. https://doi.org/10.2522/ptj.20140258

[49] Jennifer L. Rowland and James H. Rimmer. 2012. Feasibility of Using Active Video Gaming as a Means for Increasing Energy Expenditure in Three Nonambulatory Young Adults With Disabilities. *PM&R* 4, 8 (2012), 569–573. https://doi.org/10.1016/j.pmrj.2012.03.011

[50] G. Taccola, D. Sayenko, P. Gad, Y. Gerasimenko, and V. R. Edgerton. 2018. And yet it moves: Recovery of volitional control after spinal cord injury. *Progress in Neurobiology* 160 (Jan. 2018), 64–81. https://doi.org/10.1016/j.pneurobio.2017.10.004

[51] D. VanSickle, R. Cooper, and J. Ster. 1995. Wheelchair virtual joystick interface. In *Proceedings of 17th International Conference of the Engineering in Medicine and Biology Society*, Vol. 2. IEEE, Montreal, Que., Canada, 1175–1176. https://doi.org/10.1109/IEMBS.1995.579628

[52] Tracy Wall, Richard Feinn, Kevin Chui, and M. Samuel Cheng. 2015. The effects of the Nintendo™ Wii Fit on gait, balance, and quality of life in individuals with incomplete spinal cord injury. *The Journal of Spinal Cord Medicine* 38, 6 (Nov. 2015), 777–783. https://doi.org/10.1179/2045772314Y.0000000296

[53] K. Whalley Hammell. 2007. Experience of rehabilitation following spinal cord injury: a meta-synthesis of qualitative findings. *Spinal Cord* 45, 4 (April 2007), 260–274. https://doi.org/10.1038/sj.sc.3102034 Number: 4 Publisher: Nature Publishing Group.

[54] Josef Wiemeyer, Judith Deutsch, Laurie A. Malone, Jennifer L. Rowland, Maria C. Swartz, Jianjing Xiong, and Fang Fang Zhang. 2015. Recommendations for the Optimal Design of Exergame Interventions for Persons with Disabilities: Challenges, Best Practices, and Future Research. *Games For Health Journal* 4, 1 (Feb. 2015), 58–62. https://doi.org/10.1089/g4h.2014.0078