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ORIGINAL RESEARCH

Virtual community centre for power wheelchair training: Experience of children and clinicians

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ABSTRACT

Purpose: To: 1) characterize the overall experience in using the McGill immersive wheelchair – community centre (miWe-CC) simulator; and 2) investigate the experience of presence (i.e., sense of being in the virtual rather than in the real, physical environment) while driving a PW in the miWe-CC.

Method: A qualitative research design with structured interviews was used. Fifteen clinicians and 11 children were interviewed after driving a power wheelchair (PW) in the miWe-CC simulator. Data were analyzed using the conventional and directed content analysis approaches.

Results: Overall, participants enjoyed using the simulator and experienced a sense of presence in the virtual space. They felt a sense of being in the virtual environment, involved and focused on driving the virtual PW rather than on the surroundings of the actual room where they were. Participants reported several similarities between the virtual community centre layout and activities of the miWe-CC and the day-to-day reality of paediatric PW users.

Conclusion: The simulator replicated participants' expectations of real-life PW use and promises to have an effect on improving the driving skills of new PW users.

➤ IMPLICATIONS FOR REHABILITATION

- Among young users, the McGill immersive wheelchair (miWe) simulator provides an experience of presence within the virtual environment. This experience of presence is generated by a sense of being in the virtual scene, a sense of being involved, engaged, and focused on interacting within the virtual environment, and by the perception that the virtual environment is consistent with the real world.
- The miWe is a relevant and accessible approach, complementary to real world power wheelchair training for young users.

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Power wheelchair; assessment; intervention; children; adolescent; virtual reality

Background

Mobility is critical to human development and functioning. Among children with motor impairments, the use of power mobility has been linked to positive physical, cognitive and psychosocial developmental changes [1]. Furthermore, increases in independence and involvement in games, activities, and socialization with peers have also been linked to the use of power mobility among the same population [1].

In the US alone, an estimated 3.7 million community-dwelling individuals use a wheelchair to compensate for physical impairments [2], and approximately 15% of these individuals are powered wheelchair (PW) users [3]. While children have reported using their PW at home and to access public locations such as stores, cinemas, restaurants, schools and parks [4–6], they also indicated experiencing difficulties and accidents [4,7]. Difficulties included manoeuvring in confined spaces, avoiding static and moving obstacles, and negotiating uneven ground [4,7]. Examples of accidents involved tipping over, colliding with people and banging into furniture [4]. These problems are not without consequences. Due to the heavy weight of PWs, pedestrians could get injured seriously if hit by a driver. Furthermore, some youth discontinued the use of their PWs due to safety concerns or ineffectiveness [5]. Not using a PW could put children at a greater developmental disadvantage and may lead to social isolation and decreased quality of life. Furthermore, inability of a child to control a PW has also been identified by providers as a primary reason for not recommending a PW [8]. Providing children with complete and rigorous PW training is therefore essential not only to help them acquire a needed PW but also to improve usage and safety within the environments they frequent.

Among children with disabilities, developing sufficient abilities to drive a PW safely may take a few hours, months, or sometimes years depending on their levels of motor and cognitive

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impairments [8–11]. Lack of resources for PW training often prevents children from being able to acquire a needed PW [8] or, if they obtain one, from becoming proficient drivers. As an example, many paediatric PW providers in the US reported having no access to equipment, such as a loaner PW [8]. Consequently, children who require additional practice to become eligible for a PW may not be provided with this opportunity. Furthermore, PW training frequently takes place in a well-controlled environment (e.g., rehabilitation centre) which may not prepare users for the challenging real-life situations (e.g., driving in public places). One solution to increase access and opportunities for PW training among older children and adolescents is the use of a simulator, a type of virtual reality (VR) application [12–14]. In fact, a small number of children who practiced navigating a virtual PW improved their real-life PW driving skills [15–17].

The experience of presence, defined as one's sense of being in a virtual environment (VE) using a simulator rather than in a real-world setting, has been linked to better performance [18]. The experience of presence is generated by a sense of being immersed in the virtual scene; a sense of being involved, engaged and focused on interacting within the VE; and by the perception that being in a VE is like being in the real world [19]. Involvement occurs when a person focuses his or her energy and attention on executing a given task in the virtual scene [20]. Feelings of being immersed in a VE are experienced when a person perceives him or herself as being a part of and interacting within the VE [20]. Realness is the degree to which the VE appears like the real world to the person using the VR application [19,20]. Experiencing a sense of presence inside a PW training simulator is critical so that users can be invested in executing the driving manoeuvres and activities of the simulator.

Other teams have developed simulators for PW training. However, the content of their VE and/or activities lack similarities with real-life situations, thereby compromising the experience of presence. For example, the activities of the Virtual Environment Mobility Simulator consist of manoeuvring a first-person view PW inside a virtual home environment and to track and reach spherical objects using an "X" avatar [16,17,21]. The PW training activities of the simulator developed by Linden et al. [17] consist of navigating a first-person view PW on a 3-D outdoor path bordered with cacti. Thus, existing simulators generally focus on wheelchair maneuvering skills in a game-like setting, with little or no realistic environmental context.

To address these limitations, members of our team developed the McGill immersive wheelchair – community centre (miWe-CC) simulator [22,23]. The miWe-CC was developed with the intent that users would experience a sense of presence by feeling involved and immersed as if they were in the real world.

The miWe-CC simulator

The miWe-CC is a software program that may be installed on a standard personal computer. The program is controlled by a joystick, has a virtual representation of a community centre environment in three dimensions, and mimics the physical movements of an actual PW from the driver's point of view (Figure 1). The miWe-CC includes a two-storey community centre with an adjacent outdoor courtyard (Figure 2). The two floors are linked by two elevators (small and large) and contain several rooms including a library, a gym, a cafeteria, activity rooms and offices. The outdoor courtyard includes a large space with a garden and an inclined ramp. Different virtual characters (receptionist, librarian, visitors) are positioned at certain strategic locations within the community

Figure 1. miWe-CC display on PC monitor with USB joystick.

Figure 2. Virtual community centre for the miWe-CC simulator. Upper: View on the ground floor within the common area of the community centre. Lower: Second floor view with the elevator and its call button (left), glassed observation view to lower level, and offices (right).

Table 1. Quests or activities taking place in the miWe-CC.

Difficulty level	"Quest" or activity	Description
Easy	Free discovery	• Driving the simulator PW around the main level of the virtual community centre to get familiar with the environment.
	Getting a glass of juice	• Navigating through a few tables and chairs, relatively spaced out, to get a glass of juice from a virtual character at the counter.
	Getting a ball from the sports room or gym	• Navigating through a hallway, button-operated automatic door, and inside the gym to pick up a ball
	Picking up a flower from the garden	• Manoeuvring through a hallway, button-operated automatic door, and out onto the garden area to pick up a flower
Average	Getting a glass of juice and drink it at a table	• Manoeuvring through tables and chairs (more cluttered than the easy level), getting a glass of juice from a character at the counter, and driving up to a table to dink it
	Picking up a flower from the garden	• Driving through a hallway, a button-operated automatic door, across the garden, and over a bridge to pick up a flower
	Playing ball at the gym	• Getting inside the gym using a button-operated automatic door and circumventing static obstacles • Making and receiving a pass from virtual characters and scoring a goal
Hard	Getting a book from the library	• Taking the largest elevator to get to the library on the second floor • Navigating around the shelves to find a book • Returning to the main floor using a smaller elevator
	Getting candies form a vending machine	• Navigating through several tables and chairs close together and between virtual characters

centre. Virtual visitors move unexpectedly as the PW approaches, creating additional realness to the virtual scene. The application allows the user to set maximum speed limits for both forward and turning movements of the PW.

The miWe-CC allows users to freely discover the virtual space and to execute eight "quests" or activities involving the performance of tasks designed to teach or enhance PW driving skills. The completion of these activities involves using common PW skills such as driving through hallways, doors or over ramps; manoeuvring inside an elevator; turning sharp corners; avoiding obstacles; and performing parking manoeuvres. The miWe-CC activities (Table 1) are classified in three levels of difficulty (easy, average or hard) based on the time expected to complete the route, the complexity of the route and the absence/presence of static or dynamic obstacles.

The development and preliminary validation of the simulator were conducted with a user-centred approach where expert clinicians provided key concepts related to PW use in children and youth [24]. First, control of the virtual PW was modelled using movement of a real, mid-wheel PW recorded with inertial sensors and a data logger. This provided the user with a realistic driving experience [22]. Then, tasks to be performed in the simulator were selected by one member of the research team (PA), and two occupational therapists who each had over 20 years of experience providing assistive mobility devices for children and youth. Tasks were selected from PW driving assessments and training programs – including the Power-Mobility Indoor Driving Assessment [25], the Wheelchair Skills Training Program [26] and the Power Wheelchair Training Guide [27]. All PW driving tasks that could be simulated virtually were included in the miWe-CC. Tasks that were not included involved ensuring the mechanical functioning of the PW (e.g., demonstrating how to charge the PW battery) or actual body movements beyond a simple arm/hand reach (e.g., transferring from the floor back into the PW). The first version of the miWe-CC was validated and improved primarily by replacing a pool with a sports room to obtain the current version [23].

Given the importance of experiencing a sense of presence when using a VR application for real-world skills training, the purpose of this study was to investigate the subjective experience of using the miWe-CC among children and adolescents (hereafter "children"). Specifically, the objectives were to characterize the overall experience in using the miWe-CC and to investigate the experience of presence while driving a PW in the VE.

Methodology

Design

Structured interviews were used as a means of data collection. The study received ethics approval from the institutional research ethics board at each site.

Participants

Children who use a PW and clinicians with expertise in paediatrics were recruited from three Canadian paediatric rehabilitation centres: Centre de Réadaptation Marie-Enfant (Montreal), Institut de Réadaptation en Déficiences Physiques de Québec (Quebec City) and Holland Bloorview Kids Rehabilitation Hospital (Toronto). All participants or their substitute decision maker provided informed consent as per local ethics committee requirements. We used a purposeful sampling strategy [28]. Children were recruited if they: 1) were between 10 and 18 years old; 2) had been using a PW for at least a year; 3) drove their PW with a standard joystick; and 4) were able to communicate in English or French. Clinicians were recruited if they were physical or occupational therapists with more than one year of experience in paediatric assistive mobility. A minimum of one year experience in driving (children) or in providing wheelchair services (therapists) was considered necessary to compare the experiences of driving a PW in the real world versus in the simulator.

Data collection

An interview guide composed of two sections was designed. The first section consisted of three open-ended questions that inquired about participants' overall experience of using the simulator, as well as their related likes and dislikes. The second part consisted of structured questions (open and close-ended) based on the content of the iGroup presence questionnaire (IPQ) [29]. The domains (spatial presence, involvement, realness) and individual items of the IPQ questionnaire were used. The IPQ items were adapted for each group of participants (clinicians and children) and tailored to inquire about the miWe-CC, specifically in terms of participants' sense of being in the VE, their cognitive involvement/focus when interacting in the virtual scene, and their perception about the realness of the VE. To obtain a deeper understanding of participants' perception of realness specific to the miWe-CC, a number of questions were added about their driving experiences, the activities, and the obstacles in the simulator environment (Appendix 1). Generally, a topic started with a close-ended question such as "While you were driving, did you feel like you were actually part of the game?". This was followed by open-ended probes so that participants could elaborate and provide examples to clarify their answers. The questions of the interview guide were first written in English and then translated into French by two of the authors (CT, PA) who are fluently bilingual.

Prior to the interviews, participants first explored the VE (free discovery) without doing specific activities and then completed all miWe-CC activities. The simulator testing and the interview each lasted 30 min. Clinicians sat in front of the computer on a standard, fixed office chair and children remained seated in their PWs. Participants controlled the joystick of the simulator with the same hand that they used to manoeuvre a PW. Participants were interviewed in their primary language by a trained research assistant (RA) in a quiet room at each site. Interviews were audio recorded and transcribed verbatim. Basic demographic information was also collected from each participant to characterize the sample.

Analysis

Data from the first section of the interview guide (overall experience in the simulator) were analyzed using the conventional content analysis approach as they inquired about participants' overall impression of the simulator with no preconceived ideas about the data [30]. Data from the second section of the interview guide (sense of presence) were analyzed using the directed content analysis approach [30]. This approach consists of using existing theory or empirical evidence to identify key concepts or variables as initial coding categories and to operationalize these coding categories using the theory [30]. Data from closed-ended questions were categorized according to the dichotomous answers (yes/no).

Transcripts were imported into NVivo version 10 (QSR International). The content of each interview was reviewed individually by two team members (CT, PA) to provide general impressions.

For the first part of the interview, exact words that captured individual participant's experience were first highlighted from the text and researchers individually generated thoughts for initial coding. The two researchers discussed initial coding, agreed on a set of codes and sorted them into categories. While the data from the two groups of participants were pooled together to establish the main categories, results within each category were also contrasted between the children and clinicians to note any differences.

For the second part of the interview, we first highlighted all text which represented the initial predetermined coding categories of presence [30] (i.e., spatial presence, involvement and realness) and related subcategories including feeling inside the VE, playing a character and feeling like a spectator, for the spatial presence category; awareness of room surroundings, concentration and distraction while playing the game for the involvement category; and driving in the game as opposed to real life, layout and rooms of the community centre, objects/furniture inside the community centre, activities and types of obstacles for realness category. Affirmative answers to "feeling inside the VE" and "feeling concentrated" contributed positively to participants' sense of presence. Similarly, negative responses to "playing a character (other than self)", "feeling like a spectator", "being aware of the room surroundings while playing the game", and "feeling distracted" were also taken as positive evidence to the participant's sense of presence. Data which could not be coded according to the predetermined coding categories were later analyzed to see if they represented new categories [30]. Frequencies of answers per question basis (dichotomous answers) were determined [30] for clinicians and children separately.

Results

Fifteen clinicians and 11 children enrolled in the study. PW users were on average 15.4 years of age (range: 10–18), with a standard deviation of 2.9. Participants' primary diagnoses included muscular dystrophy ($n = 6$), cerebral palsy ($n = 4$), and a dual diagnosis of spinal cord injury and stroke ($n = 1$).

Overall experience using the miWe-CC

When participants were asked "how [they found] the game", all children and all but two clinicians reported feeling enjoyment from their experience with the miWe-CC. Participants attributed their feeling of enjoyment primarily to the type of activities included in the simulator, the interactions they had within the VE, and from navigating across a variety of locations within the virtual community centre. Clinicians "liked the activities that [they] were asked to do like taking the elevator" and reported that "it was fun to discover different environments like the two different floors and the bridge in the garden". Children also expressed that they had "fun moving around different places" such as "moving around at the beginning and going to the garden and the library", "finding objects and going around obstacles", and "hitting buttons to open doors". One clinician remained neutral and did not report specific likes or dislikes about the miWe-CC, while another expressed that manoeuvring from one room to another made the experience more interesting.

Experience of presence

Spatial presence and involvement

More than 70% of the participants answered that they felt as if they were inside the VE, that they were not playing a character other than themselves or feeling like a spectator of the game. In addition, more than 50% reported being unaware or only minimally aware of their real world surroundings while playing the game. All participants reported being focused on the simulator's activities, while more than 60% indicated that nothing else distracted them. Thus, the majority of children and clinicians experienced spatial presence or a sense of being in the VE, and felt cognitively involved in the virtual scene (Table 2).

Realness

In terms of realness, participants reported similarities and differences between the VE and the real world (Table 3). More than half of the participants confirmed that the miWe-CC correctly captured several locations that paediatric PW users frequently access and activities they often perform (Table 3). Their common daily real-life activities included: getting a book from the library; having to navigate between tables and chairs at a restaurant or school cafeteria, taking elevators, playing at the gym, opening and going through electrical doors and getting objects from different locations. However, participants uniformly noted that going to an

Table 2. Experience of presence of children and clinicians: sense of being in the VE and involvement.

Experience of presence	Positive impact on sense of presence			Negative impact on sense of presence		
Spatial presence/Sense of being in the VE	Children %	Clinicians %		Children %	Clinicians %	
Feeling inside the VE	82	73	"I felt I was in it" (CH9) "I felt inside the game" (CL1)	18	27	"I did not feel getting inside the game" (CH10) "I felt I was playing the game but not inside it" (CL2)
Playing a character	73	87	"Not really I was just kind of focusing on driving" (CH4) "I assumed I was me" (CL10)	27	13	"Someone in a wheelchair" (CH2) "I pretended being someone driving a wheelchair" (CL12)
Feeling like a spectator	73	80	"No, not really" (CH11) "No not like watching a movie. You feel like you are involved in it" (CL9)	27	20	"Like a spectator while at the same time learning how to drive a power wheelchair" (CH2) "I felt like watching a movie" (CL12)
Involvement/focus						
Awareness of room surroundings while playing the game	55	60	"No, not really; I was more focused on what I was doing when I was driving" (CH4) "No I was concentrated on my driving" (CL12)	45	40	"Ya, I guess, somewhat" (CH7) "Only you sitting next to me" (CH10) "There wasn't anything going on" (CL10) "If there had been something, I would have known" (CL2)
Concentration during the game	100	100	"Ya; I concentrated on keeping my hand forward to make sure I was driving forward and not going sideways and stuff and also when I had to turn I was making sure that I had enough room" (CH4) "I was concentrated" (CL2)	–	–	–
Distraction during the game	64	67	"No except when I could not go back to the reception desk and we had to restart the computer" (CH9) "No except maybe the blue lights which were not suppose to be there" (CL5)	36	33	"The software crashed" (CH10) "When the software crashed" (CL14)

CH: child; CL: clinician.

outdoor garden was less common among the target population. Finally, most participants indicated that the realness of the simulated activities and environment would help in learning appropriate power wheelchair driving skills and strategies.

All participants reported indoor obstacles as being frequently encountered by PW users in real life. When asked to compare real-life obstacles to those encountered in the miWe-CC, more than 80% of participants reported similarities while 60% reported some differences. Similarities included tables, chairs, doors and the unpredictable movements of people. Differences consisted primarily in the physical appearance of people, the way they moved by sliding on the floor (no animation of gait/leg movements), the lack of people moving around, the lack of unpredictable obstacles in the virtual scene and the lack of clutter such as misplaced furniture (e.g., chairs).

When interviewers asked children to compare the quality of their driving in the simulator versus driving a PW in real-life, three reported "driving the same way". Another child reported some similarities in quality including forward/backward driving and circumventing obstacles. This participant also reported decreased accuracy in turning and judging distances (i.e., when approaching a wall) in the simulator. Similarly, seven additional children reported a decrease of quality in their virtual driving as compared to real life mostly because "it was harder to drive with the simulator joystick" as it was "not nearly as responsive as a wheelchair joystick" or because the edges of the walls were difficult to distinguish from the floor.

Almost all clinicians reported their driving performance to be of lower quality in the simulator as compared to driving a PW in real life for the same reasons. Other reasons included the decreased field of view seen from the perspective of the simulator user, and lack of consequences upon colliding with objects. As one clinician explained, "[I] had trouble evaluating some manoeuvres from the lack of visual field" as he was unable to see the environment on either side of himself. Several clinicians recommended expanding the field of view inside the virtual scene. Specific suggestions included increasing peripheral vision, being able to look over the shoulder when backing up, and being able to see the physical limits of the PW. Some clinicians also recommended adding auditory feedback when the PW driver collides with obstacles or conversation noise to simulating people talking. One participant explained that due to lack of auditory feedback, he had been unable to tell that his "back wheel had gotten stuck in the door frame".

To further improve the realness of the virtual scene, some participants made suggestions such as improving the connectedness of simulator quests as well as adding more outdoor mobility settings, more interactions between the PW driver of the simulator and the rest of the VE, and visual/auditory information for the user. A few participants suggested that the purpose of each quest be linked to the next one on the list. For example, the tasks of *picking a flower and bringing it to the community centre reception desk* and *playing ball at the gym,* could be linked in the following way. After picking up the flower in the garden, the PW driver

Table 3. Experience of presence of children and clinicians: realness.

	Similarities (%)			Differences (%)		
Realness	Children	Clinicians	Quotes	Children	Clinicians	Quotes
Driving in the game as opposed to real life	27	27	"Yeah for sure" (CH4) "Yes, I think I drove the same way" (CL11)	73	73	"the joystick was different then my own" (CH2) "hard to see the walls as we get closer" (CH10) "decreased visual field in the game, lack of auditory and visual feedback, lack of head mobility to check the blind spot" (CL1) "the joystick was not as responsive as a wheelchair joystick" (CL8) "it was harder to judge distances between the wheelchair and the objects" (CL4) "I wasn't as careful as I would need to be in a wheelchair (…) there's no consequence when you hit something" (CL10)
Layout and rooms of the community centre	27	53	"It is an environment that looks like the everyday environment" (CH8) "It looks like a real community centre; manoeuvring in a restaurant feels natural … here [school] we have the cafeteria where there are tables; the elevators, library, all of that looked quite real" (CL1)	–	40	"There was more space to manoeuvre compared to many places in the real world" (CL12) "The garden looked more like a botanical garden; I don't know if this is the type of garden that children encounter" (CL1)
Objects/furniture inside the community centre	55	27	"The tables, glass of juice, ball looked quite real" (CH3) "The objects were realistic; the proportions were adequate [in relation to reality]" (CL12)	9	–	"Telephones, we did not see any in the game" (CH1)
Activities	73	47	"Asking for a glass, driving between several tables and chairs, playing sports, if we play with people standing on their feet, we have to be careful not to hurt them, if we get into an elevator we have to enter carefully when there are other people inside" (CH2) "Activities were the same compared to real-life; going to the cafeteria, taking elevators, getting a book from the library … " (CL4)	18	20	"I don't pick flowers" (CH9) "Maybe not picking up flowers but still go for a ride in the garden" (CL4) "If I actually had to get juice, I'd have to lean forward, I'd have to grab it. I would have to put it in a cup holder for example or ask someone to help me out. There is more complexity, obviously, in day to day, in real life rather than would be in a game" (CL10)
Obstacles-types	82	87	"Obstacles like tables, chairs, library shelves, plants, elevators, and people" (CH2) "The electric door access buttons are sometimes in a good spot and other times not" (CH10) "The elevators … sometimes elevators are small and if you have enough control you can turn around them but most times you go in one way and then you have to get help to back up the other way" (CH4) "It was pretty good like uh the way the chairs were set up and the way people kind of walk in front of you is very cool and that's just like the same as I have to deal with every day" (CH4) "Tables, elevators, doors, electrical door access button, library shelves were realistic" (CL1) "Moving obstacles, this was included; there were static obstacles too" (CL3) "People's movements could be unpredictable; we had to get around them" (CL6)	64	67	"There were less unpredictability in terms people's coming and goings" (CH2) "People do not move like this in real life" (CH11) "thresholds were missing" "Opening doors with the buttons was easier in the computer" (CH9) "The blocs in the gym, I did not know what they were supposed to represent; I thought they were obstacles but I did not know what kind; it could have been balls or mattresses or other objects like that; it felt strange to enter a corridor and have blocs as obstacles; it could have been more realistic objects" (CL1) "They don't move. If I ran into a chair it would move" (CL10) "People should be moving around more" (CL14) "There were not enough uneven surfaces on the ground; it is not always smooth" (CL15) "we can only drive forward and face the electric door access button to get the door opened" (CL6)

(*continued*)

Table 3. Continued.

Realness	Similarities (%)			Differences (%)		
	Children	Clinicians	Quotes	Children	Clinicians	Quotes
			"Having people milling about I think is very common. - and I think that the fact that they even parted ways is not always something that happens but you know, crowds of people around, is everywhere or are everywhere" (CL11)			"I think that the people were not ideal. If they are going to move it should be quicker because you don't know if you should be looking for another route"
Obstacles-amount	9	13	"I have definitely gone through that where you have to kind of maze through the chairs to get where you need to be" (CH4) "From the intermediate level onward, I thought the amount of obstacles was realistic" (CL6) "A lot of chairs represented a restricted space well" (CL4)	27	47	"The most difficult [real life] is to enter in an elevator with people already inside" (CH2) "There are obstacles like chairs, but not as much as in real life" (CH2) "I think it was far less cluttered; there is a lot more junk on the floor [in reality]" (CL11) "Everything was placed properly; in a restaurant, people move chairs and do not necessarily put them back where they belong" (CL7) "There were not enough unexpected moving obstacles that you must react to or avoid quickly" (CL3) "There could have been more people moving around" (CL5)

CH: child; CL: clinician.

could encounter a virtual character on the way to the gym and give this character the flower.

Regarding mobility, half of the obstacles participants reported as being encountered by paediatric PW users in real life are located in the outdoor environment (e.g., pavement cracks and holes, construction on the sidewalk, cars). Examples of additional PW manoeuvres found relevant for the simulator included: negotiating ramps and uneven surfaces (sidewalk curbs, cracks and holes); getting in and out of a bus using an elevating platform, street-crossing and navigating inside a parking lot; avoiding moving obstacles such as a people walking or dogs; and avoiding random obstacles such as tree branches or wet surfaces. In terms of adding interactions between the PW driver of the simulator and the rest of the VE, participants' suggestions included allowing the arm of the "person" seated in the virtual PW to reach and grasp objects in the VE, as opposed to the image of the object simply appearing next to the simulator PW upon "obtaining" it. Participants also suggested adding better visual and auditory feedback upon making a collision, such as a sound or visual information. Other suggestions that participants provided to improve the realism of the virtual scene included adding consequences upon making driving errors and providing more dynamic and unexpected obstacles.

Discussion

The purpose of this study was to investigate the subjective experience of using the miWe-CC. Specifically, the objectives were to characterize the overall experience in using the miWe-CC and investigate the experience of presence while driving a PW in the VE.

The fact that our participants experienced both enjoyment and a sense of presence when using the simulator is consistent with the literature. In a study looking at individual experiences of playing video games, Shafer et al. showed an independent association between spatial presence and enjoyment [31]. Our participants' experience of presence may have therefore contributed to the enjoyment they felt from using the miWe-CC. The same study also showed an independent association between interactivity (i.e., extent to which users can actively participate in the game experience) and enjoyment [31]. Interestingly, when our participants explained what they found enjoyable about the simulator, they gave examples of actions and interactions they performed within the VE such as taking the elevator, hitting buttons to open electrical doors, and going around obstacles.

Similar to the types of obstacles our participants reported encountering in the real world, other paediatric PW users who enrolled in previous studies indicated facing difficulties with negotiating the physical environment including opening electrical doors, avoiding static (e.g., furniture) and dynamic obstacles (e.g., people), and manoeuvring over uneven outdoor surfaces [4,5]. Hence a number of suggestions made by our participants to improve the miWe-CC such as adding outdoor mobility tasks, a greater variety of moving obstacles, and more PW driving manoeuvres in constrained spaces are expected to increase the realness of the simulator. Also consistent with the literature is that core characteristics of the miWe-CC design, including the use of a 3D virtual environment, the users' control over their performance in the activities, and the meaningfulness of the activities for the users, were previously linked to the experience of presence in other VR studies [20,32,33]. Participants in the present study suggested an increase in the degree of interaction between users and the VE as well as adding sound to the miWe-CC. Their recommendations have been supported by other findings where more interactions and better sound quality were linked with a higher sense of presence and better task performances in the VE [34–37].

Our participants' experience of presence in using the miWe-CC likely contributed to taking the virtual PW driving and accomplishment of the activities seriously and in investing themselves in the process. In the context of PW driving assessment and training using the miWe-CC simulator, users' investment in performing the PW manoeuvres and related activities may facilitate the acquisition of PW driving skills transferable to real-life situations.

Since the miWe-CC runs on a personal computer and clinicians have limited time and resources for PW assessment and training, the new simulator (despite its current limitations) could offer a safe and clinically-useful alternative. For example, prior to undergoing a full clinical assessment as PW candidates, children could start to acquire some driving skills using the simulator. Given the adjustable maximum speed limit for the forward and turning movement of the PW, and the three levels of activity difficulties (i.e., easy, average, hard), the miWe-CC could provide children with opportunities to practice PW driving skills safely and at their own pace. Becoming familiar with PW driving prior to the assessment process could potentially increase eligibility to obtain a PW and decrease the assessment duration with the clinician. Furthermore, candidates who fail the initial PW driving assessment could have the opportunity to improve their skills with the simulator before being reassessed. The miWe-CC can be installed on computers in rehabilitation settings as well as on individuals' personal home computer thereby increasing access to safe PW training particularly for individuals living in remote communities.

Study limitations and future directions

Using a purposeful sample of knowledgeable clinicians and young experienced PW users in this study limited the generalizability of our findings. Children in this study used a joystick to drive their personal PW, performed the miWe-CC driving tasks with a joystick, and the simulator's PW image they navigated inside the VE had a joystick control. The subjective experience in children who would use a different type of control to drive the simulator PW could differ from that of our participants. However, our sample of children with joystick experience had varied backgrounds/experiences and perspectives about the utility of the simulator and recommendations for improvements were consistent overall. While the miWe-CC PW manoeuvres and activities were consistent with those performed by young PW users for the most part, the miWe-CC lacked outdoor mobility activities, sound, consequences upon mistakes being made, had a visual field limited by the size of the computer monitor, and made use of a type of joystick that was different from those typically found on real PW.

Recommendations to improve individuals' overall sense of presence and perceived realism in using the miWe-CC included replacing the gaming joystick with a commonly used PW joystick; allowing the PW user to utilize a camera mode to look sideways and behind to see the wheels before travelling through a doorway or to executing a turn; adding outdoor mobility tasks; increasing the amount of natural interactions between the PW driver of the simulator and the rest of the VE; and providing additional visual and auditory information to the user.

Conclusion

This qualitative study allowed our research team to explore individuals' experience of presence in using the miWe-CC and obtain feedback to improve the simulator experience. The miWe-CC created a feeling of being present in the VE while stimulating enjoyment as the simulator captured paediatric PW users' real-life experience. However, the addition of new design features (i.e., outdoor mobility and interactivity) to the software would further enhance the realism of the virtual scenes. More robust research design methods such as randomized controlled trials should be designed to study the efficiency and effectiveness of PW simulator training compared to common clinical approaches in the acquisition PW driving competencies in the real world.

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Appendix 1. Interview guide (sample questions) and coding of answers.

Overall experience	- How did you find using the game? - Were there things you liked about the game? - Were there things you disliked about the game?
Experience of presence—sense of being in the virtual scene	- While you were driving, did you feel like you were actually part of the game? Or in the game? - Were you playing a character in the game? (if yes, give me examples) - Did it feel like you were just watching the game, like a movie? How often did this happen? Can you explain at which moments this happened?
Experience of presence—Involvement/focus	- While you were playing the video game, were you aware of what was happening in the room that we are in? When? How often? - Describe your concentration during the game. - Were there things that distracted you while you were playing the game? If so, could you describe them?
Realness	- What did you think of the virtual world of the game? - To what extent did the world of the game look like the real world we live in (e.g., images, the wheelchair, etc)? - How did you behave in the game compared to how you behave in real life? - How did you drive in the game as compared to real life? - Were there activities you did in the game which were similar to the ones you do in real life? Can you explain? - What kind of obstacles do you encounter with your PW in the real world? - In what way were the obstacles the same in the game? - In what way were the obstacles different in the game? - Who do you think should play this game?