# *WheelSkills*: Prototyping Manual Wheelchair Training through Immersive Visual Feedback


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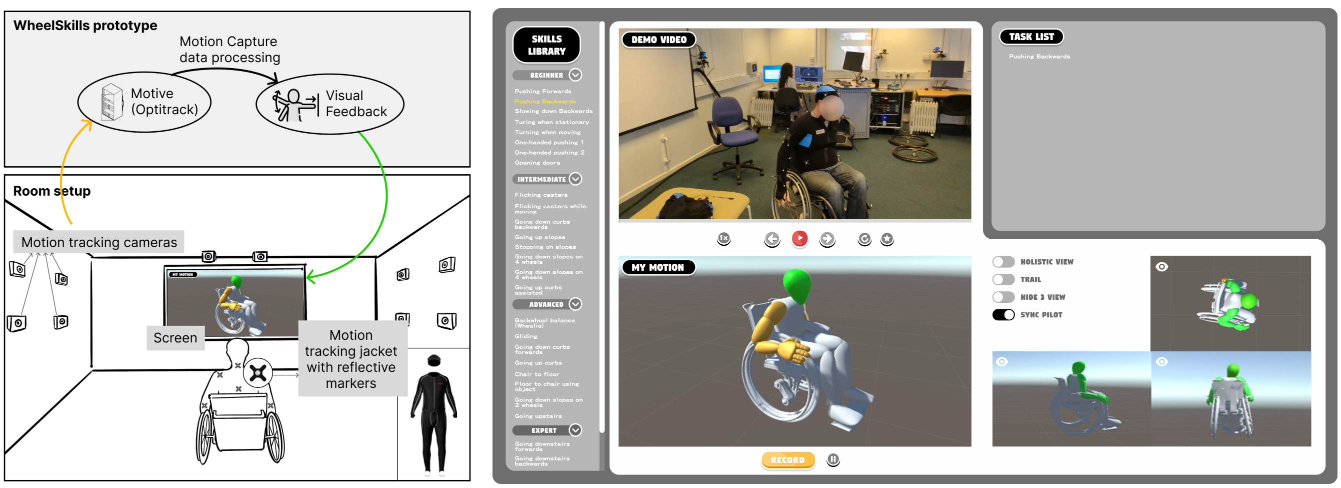


**Figure 1: WheelSkills prototype. (Left) How the system receives data and how this data is transferred to feedback. (Right) WheelSkills training interface**


## ABSTRACT

Wheelchair skills training is an essential structured process for wheelchair users to learn how to maneuver effectively, avoiding improper wheelchair use and preventing potential mobility impairments from developing. Online video tutorials have often been used for this training in familiar settings. However, video training lacks real-time feedback, affecting training efficacy in contrast with in-person training. In this paper, we propose WheelSkill, a prototype wheelchair training system combining motion capture and a training interface, providing real-time visual feedback based on the user's skeletal motion. Eight wheelchair users and a wheelchair expert trainer were consulted in a pilot focus group and interview. Results highlight themes of human-centred design principles for wheelchair users for the final iteration of WheelSkills to assimilate for a high-fidelity wheelchair training feedback system. Finally, we discuss the benefits and limitations of WheelSkills and the adaptions planned for future works.



## CCS CONCEPTS

• **Human-centered computing → User interface toolkits**.

## KEYWORDS

Wheelchair skills training (WST), Manual wheelchair users (MWUs), Motion capture, Visual feedback, Skeleton visualization, Posture correction

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# 1 INTRODUCTION

Wheelchair Skills Training (WST) is a structured process for Manual Wheelchair Users (MWUs) to learn and perform effective and efficient wheelchair control through repetitive movements, improving MWUs' ability to manoeuvre in their day-to-day lives [1, 2, 26]. These sessions generally have a trainer demonstrate techniques to the trainees, followed by the trainees replicating said movements with the trainer's feedback. WST is crucial for MWUs in terms of health and overall well-being [21]. WST allows independence and autonomy for MWUs, increasing confidence and leading to more social participation [27, 33].

Without WST, incorrect wheelchair form and posture can occur, exacerbating upper extremity impairments to muscles and joints with long-term insufficient techniques [1, 32, 35]. Access to WST can be challenging due to low awareness and inaccessibility of training program location [25]. Additionally, WST in person has disadvantages; trainees must self-correct their form based on what they observed from the trainer's demonstration [16]. Occlusions to the trainee's view of the trainer's technique can impact their ability to replicate movements [16]. Additionally, the trainee's ability to correct their posture relies on the trainer's feedback quality.

An alternative approach to in-person WST is video tutorials. The tutorials can show the trainees multiple orientations of each technique and video playback and can be used in familiar settings to the trainee [36]. Familiar settings for WST have been shown to positively affect training efficacy, performance, and wheelchair skills capacity [6]. In contrast with the in-person WST, the trainee lacks technique feedback during video tutorial use due to an absent trainer, leading to decreased motivation [2]. Lack of trainer feedback can severely reduce training efficacy due to the lack of real-time postural corrections, which is crucial to developing wheelchair techniques. Additionally, in-person WST includes additional trainees, forming a class community where interactions can boost motivation, which is absent in video WST [4, 5].

Feedback must be provided if video WST is adopted as a first-line intervention for new MWUs. Mixed reality offers video WST the ability to administer real-time feedback without the requirement of a trainer and has been shown in the literature to provide transferable skills in real-world applications [9, 16, 35].

This paper presents WheelSkills, a prototype wheelchair training system that provides postural feedback through visual cues on the user's real-time skeletal motion. In contrast with video WST, WheelSkills combines motion capture technology with an interactive training interface to create an immersive WST experience, allowing heightened user awareness of their movements. WheelSkills incorporates multiple camera angles for users to choose from, customized training options, and a skills library to enable users to practice preferred techniques. Compared with in-person WST, the multiple camera angles allow improved spatial awareness of the trainer and user, reducing the challenge of movement replication from a single viewpoint. However, due to the economic inaccessibility of most motion capture systems, WheelSkiils is used as a prototype design to gather feedback from MWU for a more practical high-fidelity iteration for future works. The aim of this paper is to explore how a WST system and immersive experiences can enable the independence of MWUs. Eight MWUs and an expert manual wheelchair trainer were consulted on WheelSkills design to determine themes from user responses to create a holistic final iteration aimed at WST.

In summary, our work provides the following contributions:

(1) Developing WheelSkills, a WST system prototype that provides real-time feedback for MWUs using the combination of motion capture and an immersive interface.
(2) Revealing system design consideration for MWU-centered feedback systems through focus group thematic analysis.

# 2 RELATED WORK

Our work takes inspiration from previous HCI research improving motor skill training through innovative feedback methods, which are reviewed with a focus on WST approaches.

## 2.1 Motor skills training

Motor skills training commonly consists of the user completing repetitious movements to learn an action or improve a specific ability related to an action. During training, a trainer often assists the trainee in learning the technique [16, 17]. Common challenges with motor skills training consist of difficulty replicating the trainers' movements when restricted to an external view or when the user is practising techniques without a trainer, requiring the user to have preexisting knowledge of the training technique [16, 17, 25]. In WST, the same principles apply, whereas there is an additional barrier of accessibility preventing access to training facilities or programs.

HCI research has applied immersive experiences with training to target motor skill training challenges. Systems such as "AR-Arm" [16] have demonstrated how an egocentric view of the trainer's movement can guide the user to complete Tai-Chi-Chuan movements. These first-person hints are provided through head-mounted displays (HMD) using augmented reality, which has shown to be an intuitive approach for at-home training [22]. However, the translation of HMD has been shown to cause motion sickness during WST [10].

Where the first person allows the user to receive detailed instructions on required movements, a second-person view lets the user view the trainer's or their posture, allowing self-feedback to correct posture in reference to the trainer, improving users' spatial awareness of their body. "My Tai-Chi Coaches" [17] and "FlowAR" [22] are both examples of a second-person view using transparent HMDs, allowing users to follow trainers' movements without interruptions. Both systems use dynamic trainer stimulus, allowing training demonstration to be present in front of the user throughout user movements. During training, "My Tai-Chi Coaches" superimpose the user's posture beside the trainers' posture so that the user can correct their posture in real-time [17]. Both first and second-person views utilizing HMDs have demonstrated advantages in executing high-precision physical actions, which could be carried over to WST [16, 17, 22].

Research has used mixed reality for surface/mirror projections so users can receive feedback not traditionally provided with standard mirrors [2, 40]. "Here and Now" [40], Sleeve AR [35], and research in sports training provided by Hämäläinen [20] have used mixed reality to aid multidisciplinary training. Both Hämäläinen [20] and Zhou et al. [40] applied embodied avatars to help perceive a temporal and spatial correlation between the body's movement trajectory and the surrounding space to support sports training and improvisational dancing, respectively.

The training mentioned above has been translated to WST through virtual environments (VE) to enable wheelchair users to proactively anticipate and acclimate to scenarios that may arise during wheelchair usage [28]. However, interactive systems for motor skills training cannot be directly translated for WST due to additional challenges such as accessibility and stigma [3, 39]. HCI approaches have been applied for powered wheelchair training (PWT) [7, 13, 18, 29, 37], where studies use a virtual environment for power wheelchair users to control with a joystick, replicating their own wheelchairs for the purpose of practising manoeuvring skills. Findings show that PWT helps participants increase confidence and wheelchair performance outside of clinical settings [7, 13]. However, a common drawback of PWT comes from the feedback from the VE, as driving in the VE has been stated to be lower quality compared to real-life driving and lacks realistic interactions [7, 18, 37]. PWT principles differ from WST as power wheelchair users train to move their wheelchair efficiently, and manual wheelchair users train to directly control their upper body to move their wheelchair efficiently. MWUs require feedback based on their body mechanics and not just the virtual environment, so these findings can't be completely replicated for MWU systems but are a good source of inspiration.

Gamification has been implemented for WST, allowing different approaches to getting MWUs to partake in training and social participation. "Geometry Wheels" [14] and "WheelchairNet" [21] are gamified WST experiences that explore HCI applications to support WST. Both systems delivered engaging physical activities for MWUs with demonstrated skill improvement in outside settings after training. However, systems revealed challenges with designing for differences in physical ability and accessibility due to systems occurring outside of home settings. Systems such as "KinectWheels" [15], a toolkit designed to integrate wheelchair movements into motion-sensing games, further enable wheelchair-accessible games to be developed for home use. Chaar et al. [10] conducted a thematic analysis on their VR manual wheelchair simulator, where participants were in a simulated space from a TV screen. Their thematic analysis found the system could help build confidence in training due to the safe environment and positive experience, which similar studies have reinforced [13].

A systematic review produced by Lam et al. [28] states the limited detail of virtual environments for WST in their reviewed papers, restricting trainers' ability to determine what training systems are sufficient for different MWUs needs. Additionally, from the author's knowledge, there are no papers that have gathered qualitative data to determine what MWUs desire for an HCI-based system for WST as opposed to qualitative feedback on system validation [10]. This may be due to a trend where able-bodied participants are recruited for these studies as opposed to MWUs [11, 28]. Thus, the present paper aims to identify MWUs' needs and explore how a human-centred training system can attempt to address them.

## 3 WHEELSKILLS DESIGN METHODOLOGY

We present WheelSkills, a novel wheelchair training system prototype, combining motion capture and a training digital interface, providing real-time second-person visual feedback based on the user's skeletal motion. The user equips the motion capture suit, allowing their skeletal motion data collected from the OptiTrack camera system to control a personalized avatar in Unity, as shown in Figure 1. WheelSkills enables users to visualize their movement through an avatar in the second person with multiple camera angles. The user can display a transparent wheelchair user who represents the pre-recording of a wheelchair skills trainer to help them with posture correction. The translucent nature of the overlapping avatar allows the user to try to replicate the movements in real-time. Additional customizations include switching perspectives, showing trails, and 3 distinct camera views.

The initial design of the WheelSkills interface was guided by a wheelchair expert trainer who was well-versed in existing WST solutions. It incorporated principles from prior literature on functional layout and readability for motion training interfaces [17, 40]. The interface divided the UI into distinct areas (e.g. task list, video feed, avatar view) to accommodate the potential distance between the user and screen, supporting varying visibility needs. The focus groups further validated the interface's ease of use and accessibility for wheelchair users. WheelSkills was designed based on a wheelchair skills trainer's feedback on the current limitations of in-person WST. The primary limitations identified with in-person WST were the quality and frequency of feedback when a trainer has a full class and a one-size-fits-all training approach, which may be less efficacious for some students. Wheelskills attempts to aid the trainers' verbal instructions with real-time visual feedback so users can correct posture more frequently without frequent supervision. Wheelskills allows users to plan their training regime to tailor their training to their needs and learning styles. However, the main focus of the study is to design a prototype and create a direction for future HCI-based WST systems to explore based on the feedback provided.

### 3.1 Motion capture and system design

The WheelSkills setup is depicted in Figure 1. The room consists of 24 OptiTrack $Prime^{X}$ 13 motion-tracking cameras and a fixed display centred in the room. The OptiTrack motion capture system was chosen for its accurate skeletal tracking, multiple camera views, and immersive visualization through 3D avatar mapping, key benefits for wheelchair skills training. The OptiTrack system was used as it is located in an orthopaedic hospital for rehabilitation. We invited the wheelchair trainer to record several wheelchair skills of varying difficulty to demonstrate in the WheelSkills interface for the trainees. A trainer's recording can be applied to a transparent avatar to allow users to reference their posture to determine whether posture correction is needed. The chosen skills were based on the trainers' existing WST classes, the feasibility

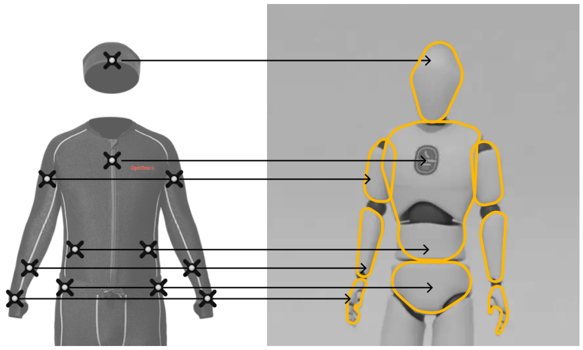

**Figure 2: Motion capture garment (left) used to map movement data to the Unity avatar (right)**

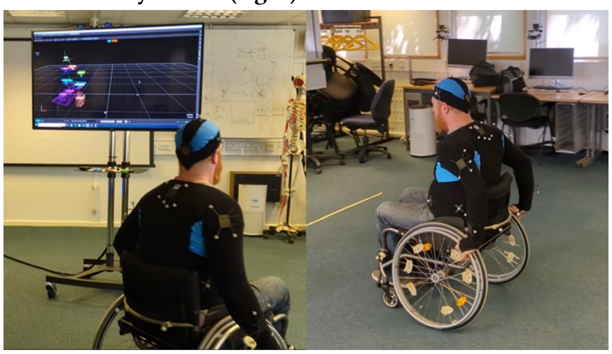

**Figure 3: A wheelchair trainer wearing a motion capture suit demonstrated various wheelchair techniques that were recorded and shown on screen.**

**Figure 4: 3D-printed bike wheel reflectors designed to hold the reflective markers for motion tracking**

of replicating the skills through the WheelSkills system, and assessing which skills were essential for wheelchair maneuverability. Some rejected skills required outdoor use or props, for example, curb-based techniques.

The OptiTrack motion capture system tracks skeletal motion through velcro garments with reflective markers. When the user equips the garments shown in Figure 2 and 3, their movement is replicated by an avatar in Unity. The wheelchair frame and wheels were outfitted with 3D-printed reflectors, as shown in Figure 4 to attach makers securely on the spokes, as the trainer pushed the wheel rims during recording, making this location unsecured to place reflective markers.

## 3.2 WheelSkills training interface

The WheelSkills training interface (Figure 1) enables users to select and view demonstration videos of wheelchair skills. The video playback could be modified by pausing, slowing the playback speed, or restarting the video. If wearing the motion capture suit, their movements are replicated by an avatar that provides real-time colour-coded feedback on the user's posture, turning body parts either green or red when correctly or incorrectly replicating the trainer, respectively. Concurrent red colour feedback indicates incorrect posture, as research shows people associate red with errors or inadequacy [30].

Users can activate or deactivate different feedback forms, enabling them to customize the received information based on their learning style. The camera angles can adjust based on user preference and can show the wheelchair trainer's transparent avatar, allowing colour feedback based on inter-posture differences.

## 3.3 Focus group design

Eight MWUs were recruited (3 (M) / 4 (F) / 1 other) with a mean age of 31 years (Min = 23, Max = 42, SD = 6.33) and wheelchair experience. Participants were recruited through UCL's local communities and the Wheelchair Skills College. Maximum variation sampling was used to obtain diversity in age, gender, disability type, and wheelchair experience. All participants were screened through an online questionnaire, which collected information on demographics, wheelchair skills experience, training needs, and technology familiarity. Information on participants' specific injuries was not collected due to ethical considerations. Two focus groups were created from all participants (four participants in each group), and each group had a researcher knowledgeable in WST and a wheelchair skills trainer to assist with the discussion.

Participant information is presented in Table 1 All focus groups were conducted online due to the following two factors. Firstly, access to the motion capture systems was not fully accessible, and getting all participants prepared to use the system would have excessively increased the time and coordination required for all participants to partake in their focus group. Secondly, the primary focus of the focus groups was to receive feedback from Wheelskills so that future WST systems could be produced based on MWU feedback. Therefore, the online settings were an efficient option, with a video demonstrating WheelSkills from the user's perspective.

**Table 1: Focus group participant's wheelchair experience**

| Participant | Age | Gender | Years as a MWU | Previous WST |
|---|---|---|---|---|
| 1 | 39 | Male | 12 | Yes |
| 2 | 24 | Male | 2 | Yes |
| 3 | 29 | Female | 4 | Yes |
| 4 | 30 | Male | 5 | No |
| 5 | 24 | Female | 5 | No |
| 6 | 42 | Female | 4 | Yes |
| 7 | 30 | Male | 4 | No |
| 8 | 25 | Male | 2 | No |

Semi-structured guides were developed based on the literature review of wheelchair skills training and technology use [14]. Questions aimed to elicit insights on user needs, challenges faced, and reactions to the WheelSkills system. The guides were pilot-tested with 2 wheelchair users and refined prior to focus groups and interviews. The focus groups started with a walkthrough video of WheelSkills explaining how to use the interface and its rationale. Participants were encouraged to ask any questions about the system during discussions. Afterwards, the researcher asked semi-structured questions on users' reactions to WheelSkills, opinions on system improvements and preferred training styles. Each group lasted an hour, followed by a trainer's feedback interview.

## 4 RESULTS

The study results are organized into two parts: (1) focus group feedback and (2) wheelchair trainer interview feedback. Following the deductive thematic analysis outlined in [8], We conducted a deductive thematic analysis to develop a holistic understanding of current practice and challenges of WST and learning from both experienced and less-experienced users' perspectives to evaluate the potential of WheelSkills. Two researchers independently coded all transcripts and then delved into hidden meanings and interlinked relationships between codes. Codes were categorized into themes based on their relationships to identify insights into human-centered wheelchair design. Through iteration, we sorted connected categories into higher-level themes.

### 4.1 Focus Group: WheelSkills Evaluation

After thematic analysis, five themes were grouped from the focus groups.

*4.1.1 Theme 1: Feedback.* Participants agreed that using visual feedback is the favored feature of the system. Postural correction would "appear clearer, allowing efficiency in their corrections" (P1). Clear prompts can "save them from getting injured or having muscle cramps" (P1). The colorization of their avatar made it easy to "interpret the correct posture" (P4). The visualization of users' bodies enables them to "see [themselves] just like in a mirror" (P5) to "see the right position when doing a wrong [movement]" (P4). Compared to a regular mirror, users can see "all sides of their body from different angles" (P5), enhancing "self-awareness (P6)" and "self-correction" (P6) capabilities.

However, one of the users found the "multiple camera angles to be somewhat sensory burdensome and excessive" (P5), instead of "feel[ing] more focused on the "My motion" window" (P4). Whereas "the three views will be [..] helpful when doing skills like back wheel balance pushing" because users need to observe their substantial movements at a particular angle. Users feel they need to choose which view to zoom in on to accommodate the perspective needs of different skills. Therefore, "hide three views 'is a great option [for] users to make their own decisions" (P4). Regarding quantitative correction feedback, one participant stated that "even with the transparent trainer avatar demonstrating the correct technique, it was [unclear] how far away he would be from the correct posture" (P2). They wished that "the distance could be quantified through instructions" (P2), e.g., by showing that "it takes another 5 inches for the hand to reach [the correct position]" (P2).

*4.1.2 Theme 2: Transition Learned Skills to Outside Settings and Accessibility.* When asked how confident they could transition their learned skills outside, they stated, "This transition would only occur if they were very proficient in the specified skill" (P4). A participant stated, "[An] [i]ndoor training environment with nice flat surfaces is quite different from actually using the skills outdoors with bumps and cracks" (P5). "Adding different backgrounds in the motion video like pavements or other settings to give some context" (P5) could help to improve "situational awareness and confiden[ce]" (P5). Based on this feedback, the addition of props such as "doors" (P6), "curbs" (P6), and "slopes" (P5) to the training scenarios could immerse users in virtual outdoor settings.

Participants also stated, "[they would have] to travel to the location where [WheelSkills] was installed and wear a motion capture suit, which [prevented] use at home" (P6). On the other hand, some participants felt that "it was an experience that could not be obtained by training [by themselves] at home" (P2).

*4.1.3 Theme 3: Need for Personalising Interfaces.* Participants unfamiliar with motion capture technology stated, "We would prefer assistance to fully understand the system" (P4) so they can use WheelSkills independently in the following sessions.

Participants requested increased interface customizability, as "not all users will need to see the same information" (P8). The task list is "a good tool for managing training plans" (P3) and can "add a tick box to record what [skills] has been [practiced] (P8)", but "does [not] need to be constantly present" (P7). Each user should "choose to show the window [they] would like to see and pick one window to make it larger whether [that's] the demo video [or their] own motion" (P7). The same goes for the "My Motion" avatar. Participants "would like to customize the color indicator or the presence of the trainer's avatar" (P5) and "choose what layers are on that [avatar]" (P5). Avatar tailoring would allow users to "[customize] different ways of tracking [feedback]" (P6). The system should "give the user the [...] option to choose whether you need [a] function" (P7). It "should [not] [decide] on your behalf" (P4).

*4.1.4 Theme 4: Gamification and Avatars for Enhancing Engagement.* Participants stated that WheelSkills converted into a more gamified experience could boost engagement. For instance, "people [can] get three total greens after three attempts [to] get a point" (P6), "creat[ing] a scoring board to see behaviors of different users" (P5), and "show [users] total distance traveled, number of errors, [and] levels of improvements made" (P5). A competitive experience could add a peer learning element, improving engagement and motivation. Furthermore, as WheelSkills develops, users can "post and share their training videos and get feedback in a community-based setting" (P6).

Some participants agreed that including "a user's own customized avatar [could] represent different cultural backgrounds and identity personalities" (P6), which could help " [users] learn from those they want to learn from" (P2).

### 4.2 Wheelchair Expert Trainer Interview

In our focus group, some users had not been exposed to motion tracking systems before, so they misunderstood the reflective markers' function as buttons to control their wheelchairs. This misunderstanding led to the realization that we needed to consider the cognitive characteristics of each user. The trainer discussed an onboarding process to guide new users through the system's features, providing clear instructions, tutorials, and tooltips to ensure a smooth introduction to the platform.

In our 1.5 hour feedback interview, the trainer agreed with adding different props, surfaces, obstacles, and terrain to WheelSkills to make translating to outside settings easier. By practicing in scenarios with contextual elements, users improve their situational awareness and learn to anticipate and react to potential challenges. Training in virtual outdoor scenarios hones users' ability to adapt their skills to different situations, boosting their confidence in real-world applications and, at the same time, preparing them for real-world use in a safe environment. Additionally, the translation of WheelSkills to a mobile application for users with mobile motion capture equipment stated by the trainer could allow an outdoor training environment, which our current motion capture system could not achieve.

Overall, the trainer agreed with the focus group's feedback on peer learning and how peers with similar skill abilities could virtually train together, fostering a sense of community, healthy competition, and mutual support, increasing participation and motivation. However, adding different feedback modalities was not discussed in the focus group. Excluding quantitative feedback, considering audio cues or haptic feedback to guide the user through the correct action could provide additional assistance, especially for users with limited visual perception.

Skills assessments were discussed by monitoring progress from basic to advanced practiced skills, allowing users to build a foundation of skills before they tackle advanced techniques. By implementing a timeline of mastered skills, the user has a comprehensive view of the WST journey while also enabling the user to set long-term goals and track their progress, giving them motivation and a clear sense of purpose.

## 5 DISCUSSION AND FUTURE STEPS

From the focus group feedback, the concurrent visual feedback for posture correction from WheelSkills had positive impressions. Visualizing the user's skeletal model was believed to enhance self-awareness and allow for self-correction of movements and alignment. However, the primary aim of this paper was to explore feedback from MWUs to determine the needs and wants of immersive visual feedback systems. Combining the findings from our identified themes, we highlight insights into future human-centred feedback systems for WST.

The request for tailored, immersive, flexible training experiences was highlighted to accommodate diverse needs and preferences in training styles. The tailored feedback was stated due to some participants finding specific feedback redundant. As users emphasized, everyone trains differently, a replicated challenge for WST identified by Gerling et al. and Inman et al. [14, 21]. However, as the adaptability of systems and interfaces increases, so does the technical challenge of designing and using the system. It is of great importance to design personalization tools that are both flexible and intuitive. This would enhance user autonomy, enabling tailored training by selecting training goals, progression pathways and offering assistive features.

Implementing skills assessments and tracking progress from basic to advanced stages can increase user motivation and provide a clear, long-term, goal-oriented road map for the user's training journey [34]. Particularly, numerical metrics and quantitative feedback can facilitate self-assessment and posture correction. For instance, physiological sensors and processing interfaces can be integrated into WheelSkills to measure users' body states and reflect the information together with trainers [23, 24, 31]. Further, as suggested, integrating other feedback modes, such as audio cues or haptic feedback [12, 19], could provide additional guidance through multimodal sensory experience. Drawing on the principles of motivational psychology and gamification [14, 21, 35], design features that provide positive benchmarks, incentives, and community can increase adherence to training. However, presenting multimodal data streams in intuitive formats for WST remains a challenge due to the management of information overload. Research is needed to determine optimal feedback modes and systems that avoid cognitive overload for MWUs.

Immersion was considered when designing WheelSkills to motivate users to engage with the training so the transition from the virtual environment to the outdoor environment would occur with improved confidence. Similar to Inman et al.'s immersive WST virtual environments [21], the provided immersion improved wheelchair skills and confidence in navigating outside environments. Due to the online nature of the focus group, the WheelSkills system wasn't effectively evaluated based on immersion. However, the general impression suggested that the system could effectively immerse users in a virtual WST setting. Adding different ground surfaces, obstacles, doors, curbs, and other contextual elements would enable training in simulated real-world conditions.

Flexibility was requested so that training environments could adapt depending on the trained skill and a system that would be affordable for many users. Incorporating the WheelSkills fundamentals into an AR application on a mobile phone [38], for instance, could incorporate this flexibility into WST systems. This AR mobile application could replicate gamification principles [14, 21, 35] that could connect like-minded MWUs to allow peer learning and interaction, increasing adherence to user training. The addition of extra physiological sensors for assessment was believed to enhance this engagement between peers by engaging an element of competition in training. Future research can explore how these additions affect WST. The future iteration of WheelSkills will incorporate these additions for evaluation in a user study with MWUs, especially including wider demographics (e.g., older individuals), to understand its applicability and feasibility in real-world settings.

## 6 CONCLUSION

This paper presented WheelSkills, a novel wheelchair skills training prototype aimed at gathering feedback on immersive visual feedback systems. The primary focus of this study was to explore a holistic approach to how human-computer interaction can assist with the challenges of wheelchair skills training based on manual wheelchair users' focus group feedback. The contribution of our work includes (1) WheelSkills, a novel prototype used for WST and (2) MWUs' feedback on what they desire from an HCI training system.

Results highlighted the benefits of immersive visualization for posture correction and spatial awareness, additionally identifying themes that can improve wheelchair training outcomes. Further research is required to explore how physiological parameters can be integrated and understand control on practical environment translation. Future research, in turn, could allow a training system that focuses on empowering manual wheelchair users through customization, community, and adaptive interfaces, greatly benefiting the health, mobility, and independence of wheelchair users.

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