Game-based Powered Wheelchair Skills Training: Examining Tensions Between Player Engagement and Therapeutic Requirements

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ABSTRACT

Wheelchair skills training is key for achieving greater personal mobility, and interactive solutions offer the potential for a more engaging training experience. In this paper, we examine the tensions between therapeutic requirements and player engagement, through the prototypical development of a wheelchair skills training game for children with Cerebral Palsy. Using an iterative and interdisciplinary design process, exercises from the Wheelchair Skills Program manual are implemented as interactive missions in an open-world, medieval-themed game. The game contains a custom input system that directly uses the player's wheelchair input peripherals. In bridging the gap between clinical requirements and player engagement, we discuss the challenge of repetition and feedback in therapy, and implications for future work in game design.

CCS CONCEPTS

• **Software and its engineering** → **Interactive games**; • **Human-centered computing** → *User centered design.*

KEYWORDS

wheelchair training, iterative design, interdisciplinary design, games, virtual training

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1 INTRODUCTION AND BACKGROUND

According to the World Health Organization around 1% of the global population requires a wheelchair for personal mobility [28], and there is ample evidence that personal mobility is key for achieving a greater level of independence, social participation, and quality of life [4].

However, this requires access to structured and clinically validated opportunities for wheelchair skills training [17], but only a limited fraction of new wheelchair users have access to these [2]. A lack of time, money, resources and clear instructions are barriers which prevent therapists from providing validated skills training [2].

Considering these challenges, interactive solutions offer an interesting avenue to create interventions for wheelchair skills training that have the potential to engage users [10] and are effective in skills transfer [7]. For example, Harrison et al. developed a virtual wheelchair skills training simulator for adults with neurological impairments [13]. To facilitate learning, their design follows an errorless learning approach [18]. However, it is mainly focused on simulating real training exercises with no further consideration for user engagement [22]. Likewise, Drisdelle et al. designed and implemented a head-mounted virtual wheelchair skills training game for children working with experts for clinical feedback during design [6]. The head-mounted approach was used to increase user engagement, and exercises were considered as levels which contained a scoring system, power-ups and a reward system to gamify [12] the training experience. To evaluate the use of gaming systems in therapy, Faure et al. compared game-based vs simulator-based powered wheelchair training [8]. They measured an improvement in wheelchair skills and driving confidence for both training types. Additionally, the simulator training also increased real-world powered wheelchair skills. The game used in this study is a racing game with no specific therapeutic value in mind. The simulation is a recreation of daily tasks in a virtual world. Building upon this knowledge, Zondervan et al. combines physical wheelchair training with game-based therapy by integrating both systems into their Kinect-Wheelchair Interface Controlled smart wheelchair trainer [29]. After a year-long usability study with 8 therapists and 8 children, the therapists noted that the system allowed them to train more children in comparison with a demo-wheelchair setup and regarded the system as safer. The therapists also noted the game integration increased motivation and engagement, however, the shared control system was perceived as counter-productive.

Likewise exploring technology-guided wheelchair skills training, a recent survey [5] touching upon methods used in virtual wheelchair skills training highlights that virtual wheelchair skills training lacks a standardized assessment protocol, outlining a key research challenge going forward. More recently, this was addressed by Giesbrecht et al. [11], who contribute a gamified mHealth[1] manual wheelchair skills training program. Their program is built upon the grading system defined by the Wheelchair Skills Program (WSP) [16]. Their results indicated a 5% improvement in skill capacity and high effectiveness for participation of activities in the community. However, practical deployment requires patients to continuously shift attention between the tablet and their environment, which is particularly challenging for children in the context of powered wheelchair use.

In our work, we address this gap by developing a game-based solution for wheelchair skills training that builds on the WSP [16], and places the same emphasis on game design and player motivation as it does on therapeutic requirements. In particular, the game is intended to support wheelchair skills training among children with Cerebral Palsy (CP), which is one of the most common causes of disability among children [19]. For this group, the effectiveness of wheelchair skills training was recently demonstrated by Naaris et al. [20] and more specifically the effectiveness of the WSP[15][27]. In this paper, we outline our design and development process, and highlight challenges for the design of rehabilitative technology that seeks to accurately integrate clinical protocols and combine them with engaging gameplay.

2 DESIGN AND DEVELOPMENT OF ROLLABILITY: AN EVIDENCE-BASED GAME PROTOTYPE TO SUPPORT WHEELCHAIR SKILLS TRAINING

Here, we describe our design process and the resulting system with a focus on the integration of the WSP [16] and implications for in-game tasks, adaptation, and assessment of player performance.

[1]A telehealth approach, which uses tablet or smartphone applications to perform rehabilitative exercises at home.

2.1 Iterative and Interdisciplinary Design Process

The development of the prototype follows an iterative and interdisciplinary design process, and is rooted in previous work that examined children's preferences with respect to game-based wheelchair skills training [10], and demonstrated their interest in the concept. Clinical experts are actively involved as they will be able to assess the application throughout the development stages: Our team consists of researchers in physiotherapy and Computer Science (CS) who work together on a weekly basis to assess the current state of development, the clinical requirements and the gameplay of the game. Once a month, the assessment group is expanded by professors from both disciplines to evaluate the state of the game on a broader scope.

In the initial phase of the design we analysed the WSP manual [16] for clinical standards regarding the training setup, and grading in conjunction with powered wheelchair training. These standards were then used to define a set of feasible features to recreate the exercises virtually. The feasibility of features was determined by an interdisciplinary appraisal, where the clinical importance was weighted against the virtualization complexity and potential of the feature. Next, we evaluated how these virtual exercises fit into the actual game design: In this step, it was discussed whether a virtual exercise or its features offer opportunity or hinder the motivational pull of the game. This process is repeated multiple times with different challenges as focus point, including the ability to measure outcomes, exercise adaptability and virtual wheelchair behaviour.

At the current stage, we limited participation in design to academic stakeholders to establish a framework which will be used to invite children to contribute to the design process. This was done to facilitate the bridge between clinical and design requirements without placing a burden on the target audience and to ensure that a first experience prototype would be accessible and available to them to ground conversations.

2.2 RollAbility: A Game to Support Wheelchair Skills Training

2.2.1 Gameplay. RollAbility is a medieval-themed open-world game in which the player can drive around freely. Within the world, specific locations are associated with missions. These include game elements (e.g., fishing with a chance of catching random objects, sorting items in shopping carts, watering flowers in a dried-out garden) which are designed around the WSP tasks and require the player to perform a specific skill. After a mission is done, the player can drive around freely and choose a new mission. Only the missions which are relevant to therapy are unlocked by the therapist. To start a mission, the player has to drive toward an indicated point of interest. This can for example be an old house with a Non Playable Character (NPC) in front, as seen in Fig. 1. We hypothesize that free movement in between exercises and the choice of mission allows the player to feel a sense of autonomy, which is important for the motivation of the player [1]. After every completion, the player gains a random item (e.g., painting, campfire, pet) or player skin (e.g. zombie, robot, farmer) which they can decorate their virtual house or change their appearance with. Once all required missions for the training are completed, the player gets the choice to freely roam around the world and interact with multiple interactive experiences. These experiences are all the missions which are unlocked, and the virtual house where the player can decorate the house with the collected items from the missions.

2.2.2 *Player Interaction.* The game is controlled using the control mechanism of the player's powered wheelchair. To achieve this, a setup was developed which uses an R-net Input-Output Module (IOM) [24], that is connected to an Arduino. The latter in turn is connected to the computer running the game. This is illustrated in the schematic in Fig. 1. The IOM represents an additional operating mode in the wheelchair configuration. This allows us to create a separate gaming profile on the wheelchair to block the player input from physically moving the wheelchair and output the signal from any R-net input peripheral. As some children with CP use head-foot steering systems while others use a joystick, this approach allows both groups to interact with the game using their comfort mode of interaction.

The player avatar is a person who uses a powered wheelchair; a challenge here is to create a realistic representation of the wheelchair in terms of driving behaviour. At the beginning of the training session, players get the option to choose an avatar, allowing them to adjust how they are represented in the game. Apart from the avatar, the game contains a virtual display mirroring the same display as used with R-net joysticks[25] or Omni devices[26]. This way, the player learns how to read the display which will also provide feedback when using their wheelchair in the real world.

2.2.3 *Integration of WSP Tasks.* As previously described, the training tasks are designed on the basis of the WSP [16], and are integrated into the game as separate missions, allowing us to create a structure that resembles traditional training. Each task describes an exercise for training one specific skill (e.g., Roll forward, Turn in place, ascending ramp). The missions represent assignments that the NPC medieval villagers within the game world request the player to do (e.g. a fisherman asks you to catch some fish, a merchant asks you to sort his goods). During the tasks, audiovisual feedback is provided to improve the intrinsic motivation of doing the exercise. While the player is performing the exercises, the accompanying therapist can adjust the parameters of the exercise to adjust the difficulty. For this, we build upon the expertise of the therapist to assess the motivation of the child and to use both verbal encouragement and adaptive exercise difficulty to stay within the flow area as described by Nakamura et al. [21] [1]. As a reward for doing these assignments, the player unlocks items for their house or a new skin for their character, providing additional extrinsic motivation.

3 DISCUSSION

Here, we discuss challenges and opportunities for games to support wheelchair skills training with a focus on bridging the gap that arises when reconciling clinical requirements with goals for game design and player engagement, and the limitations and avenues for future work within our project.

3.1 Reconciling Clinical Requirements With Game Design for Player Engagement

The primary goal of game design is to provide an engaging interactive experience for the player. To make the interactive experience entertaining, the game design builds upon psychological needs to increase player engagement with the system [3]. This can be in conflict with rehabilitation routines, where the primary goal of wheelchair skills training is to improve wheelchair skill [17] under tight time constraints [1].

While a similarity between game design and therapy is that they both work towards a certain goal [1][3], the implications are different. In therapy, tasks are set and evaluated to meet clinically relevant criteria [16], and can be repetitive. In game design, player motivation is foregrounded, and to this end, varied gameplay may be needed. Here, a challenge is to find design strategies that offer players varied experiences and still accurately integrate therapeutic protocols without compromising player motivation [3]. For example, game design could employ reward strategies that encourage engagement with repetitive tasks [9], or associate one training exercise with different levels within the game that vary in terms of in-game task and visuals.

3.2 Player Performance: Assessment and Feedback

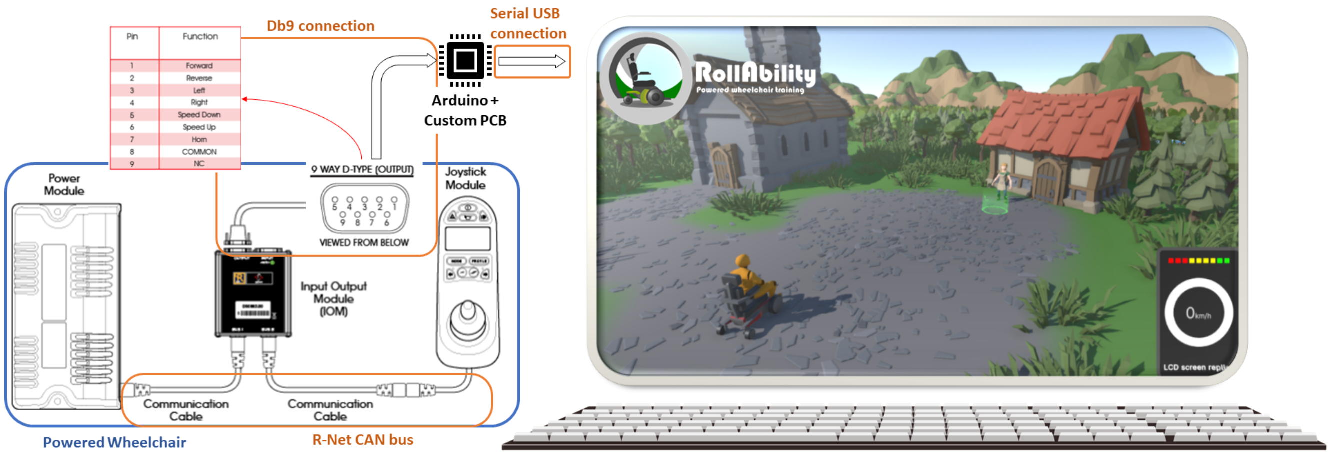
Correction and feedback are key aspects of wheelchair skills training and need to be addressed in game-based solutions. In a previous study, it was highlighted that therapists use situational factors and individual traits of the patient to evaluate which feedback and correction is required [1]. Feedback is delivered verbally, but also haptic, and highly tailored. Game technology can only rely on calculated performance and sensor data to approximate the therapist's assessment, highlighting a bottleneck in the translation from therapy to games.

Here, we believe that game-based therapy should not replace, but augment what therapists can provide, implying those therapist's should therefore still be part of the gaming process. To address this issue, we implemented a second controller app, which gives therapists access to in-game performance data, and allows the therapist to adjust exercises in the game with the use of the app. In this way, we hope to reintroduce the detailed adjustments of therapists. However, this is not without challenges. Although therapists have clinical knowledge of adjusting parameters, this does not apply in gameplay situations. To address this, the app will indicate how the game would have evaluated player performance based on available parameters. This information will be provided to therapists to potentially supplement their individual assessment of the situation. A challenge for future work will be to determine how to balance both ways of assessing player performance, how to adequately communicate uncertainty to therapists, and how to ensure they will remain in a position to apply their own judgement rather than becoming reliant on a technical solution.

3.3 Limitations and Future Work

This paper examines the interplay between game design, player engagement, and clinical requirements in a game to support wheelchair skills training. In a study by Jung et al. [14] the engagement of

Figure 1: Input system schematic and RollAbility game screenshot



stroke patients in game-assisted therapy is considered through the therapist's perspective. They perceive a highly engaging game as a distraction, where the patient will focus on finishing the game goals and not the rehabilitative goals. This shift in perspective highlights the need to consider the therapist's experience in more depth. However, at the same time, to live up to the promise of a motivational pull [23], games need to engage patients, particularly when working with children. In our future work, we plan to involve children in playtesting to further examine how to fulfil their expectations of digital games, and whether and how these can be reconciled with therapeutic requirements.

4 CONCLUSION

In this study, we examined the tensions between player engagement and therapeutic requirements for game-based powered wheelchair training. Using an iterative and interdisciplinary design approach, we used the Wheelchair Skills Program manual [16] to formulate a game design based upon standardized training methods. To reconcile clinical requirements with game design for player engagement, we discuss the challenge of repetition and feedback in therapy, and the implications for future work in game design.

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