Lean on Wii: Physical Rehabilitation With Virtual Reality and Wii Peripherals

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Abstract. In recent years, a growing number of occupational therapists have integrated video game technologies, such as the Nintendo Wii, into rehabilitation programs. 'Wiihabilitation', or the use of the Wii in rehabilitation, has been successful in increasing patients' motivation and encouraging full body movement. The non-rehabilitative focus of Wii applications, however, presents a number of problems: games are too difficult for patients, they mainly target upper-body gross motor functions, and they lack support for task customization, grading, and quantitative measurements. To overcome these problems, we have designed a low-cost, virtual-reality based system. Our system, Virtual Wiihab, records performance and behavioral measurements, allows for activity customization, and uses auditory, visual, and haptic elements to provide extrinsic feedback and motivation to patients.

Keywords. Virtual rehabilitation, tele-rehabilitation, virtual reality, Nintendo Wii

Introduction

The use of low-cost, commercial gaming systems for rehabilitation has received substantial attention in the last few years. Systems such as the Nintendo Wii encourage players to use natural actions to play games (e.g., swinging the arm to roll a bowling ball, or jogging in place to make a virtual character run). The Wii (and similar systems) has been integrated into rehabilitation programs [1] and has gained the support of occupational therapists because it is easy to use and has a wide variety of games available. While the Wii does have benefits, the games are not designed specifically for rehabilitation, leading the Wii to have many limitations: it cannot accurately monitor and track patients' progress, games are often too difficult for patients, and there is a lack of appropriate and motivating feedback for patients. By combining the benefits of Virtual Reality and the Nintendo Wii, we have developed a rehabilitation system, Virtual Wiihab, that can be used in the hospital (by a patient with a therapist) or at home (by a patient, monitored over the Internet by a therapist).

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1. Wiihabilitation Today

The Nintendo Wii has been adopted by a number of practitioners to assist in the treatment of various impairments. The Wii has been successful because the environments that it creates are entertaining, thus encouraging patients to continue therapy for longer periods of time [1]. Typically, Wii Sports games such as boxing, bowling, or golf are used during therapy sessions because they encourage gross motor movements [2]. One study using Wii Sports reported increased postural control and visual perception in an adolescent with cerebral palsy [3].

Most recently, the Wii Balance Board was used to improve balance and stabilitiy. Following the use of four Wii Fit games that use the Balance Board, one post-stroke patient showed improvements in various measures of motion and balance (e.g., timed up-and-go, functional reach and the Berg balance scale) [4]. A separate study compared Wiihabilitation treatments to traditional treatments and found that Wii-based interventions result in similar improvements in functional outcomes [5]. This study also reported higher levels of patients' satisfaction with the Wii-based rehabilitation compared to a standard rehabilitation regimen.

While the Wii has had much success in rehabilitation, it has a number of problems that prevent it from becoming widely adopted for rehabilitation:

- The motions and interactions required are not focused on rehabilitation outcomes, such as increasing range of motion or muscle strength.
- Game difficulty is calibrated to healthy players, making many games unplayable or too challenging for people with physical disabilities.
- The game scores or progress measurements that are provided are too generic, making them insufficient for tracking patient progress.
- Therapists cannot observe patient progress, watch for cheating, or monitor compliance when patients play games in tele-rehabilitation scenarios.
- There is currently no rehabilitation-specific feedback provided to patients to help guide or motivate their movement or motions.

2. Virtual Wiihab System

The Virtual Wiihab system consists of a standard Windows-based PC in conjunction with off the shelf Wii peripherals. Virtools 4.1 was chosen as the software backbone of the system because it has an add-on package that enables virtual environments to be exported to Wii Console disks or distributed via WiiWare. By combining Virtools with the SNaP framework [6], it is easy to retarget each activity for a CAVE, a head mounted display, single or multiple computer monitors, or a television.

2.1. Overview

The Virtual Wiihab system addresses the Wiihabilitation deficiencies identified in Section 1 in a number of ways:

Rehabilitation focus. Each activity was designed with specific target areas or disabilities in mind. In some activities, patients are encouraged to work on movement precision and postural control, and in other activities patients are encouraged to work

on their balance and stability. There are also no loading screens or time-wasting animations. This ensures that patients have the opportunity to maximize the amount of time they spent performing rehabilitation activities.

Customization. Each activity can be customized to meet patients' skill sets or limits of mobility. Across all activities, the sensitivity of the Wii Balance Board (and Wii Remote) can be modified to encourage large movements in patients who do not move very much, or to encourage small, accurate motions in patients who make uncontrolled, spastic movements. Other customizations allow therapists to change the speed of moving objects, the number, size, and location of goal objects, and the frequency and number of stimuli. These customizations allow therapists to change task requirements as patient progress through their rehabilitation program.

Measurement. Virtual Wiihab can record a number of behavioral and performance measurements. The system can record data from the Wii Balance Board and Wii Remotes (e.g., accelerations, button presses, weight distribution, etc.) as well as a number of time-based measurements, such as the time-on-task, the time between user interactions, or the duration of actions (e.g., how long a button is pressed down or how patients' centers of gravity are distributed over time). Recordable performance measurements include the final activity score, the number of 'missed' stimuli, and the number of actions patients perform (e.g., the number of objects thrown).

Feedback. Virtual Wiihab presents patients with a variety of extrinsic feedback cues. Auditory feedback can be played through speakers. Visual feedback can be presented using overlays (e.g., an on-screen Balance Board sprite). Haptic feedback can be presented using the 'rumble' feature on a Wii Remote. Therapists can specify the type of feedback (e.g., visual, auditory, or haptic), the feedback schedule (e.g., concurrent, terminal, or delayed), and the intensity of feedback.

Monitoring. The use of a simple web service allows Virtual Wiihab to be used for tele-rehabilitation purposes. Performance and behavioral measurements can be uploaded and viewed using a web service and authorized web clients. Web clients can enable patients and therapists to view charts, graphs, or animations of task compliance and progress, and should help to identify areas of improvement for the future.

Multi-Player. Each activity can support both single and multiple player interactions. This allows patients to work with other patients, or to interact more directly with their therapists. This functionality has the potential to motivate patients to continue an activity longer than if they were doing it on their own.

2.2. Rehabilitation Specific Activities

The Virtual Wiihab system contains four activities (Snowball Fight!, Mouse House, Startle Fish, and Alien Abduction) that aim to increase trunk control, lower extremity stability, and patient balance. Each activity is suitable for the young and old, as well as a variety of patient abilities. To increase patient compliance and motivation, each activity can be played competitively against a partner (e.g., a family member, a fellow patient, or the therapist).

In Snowball Fight activity, a patient is standing, sitting, or kneeling on a Wii Balance Board and is required to lean from side to side to dodge incoming snowballs that are thrown by an opponent. In order to throw snowballs at an opponent, the patient uses a Wii Remote. The speed, angle, and distance of a snowball depend on the motion of the Wii Remote in the air. If a snowball hits the patient, the Wii Remote in their hand rumbles. Snowball Fight should encourage a patient to work on their dynamic

postural control and movement accuracy. Snowball Fight can be played individually or with a partner. In individual mode, the patient plays against a computer-controlled enemy penguin that is throwing snowballs at the patient. If played with a partner, the partner plays the role of the enemy penguin.

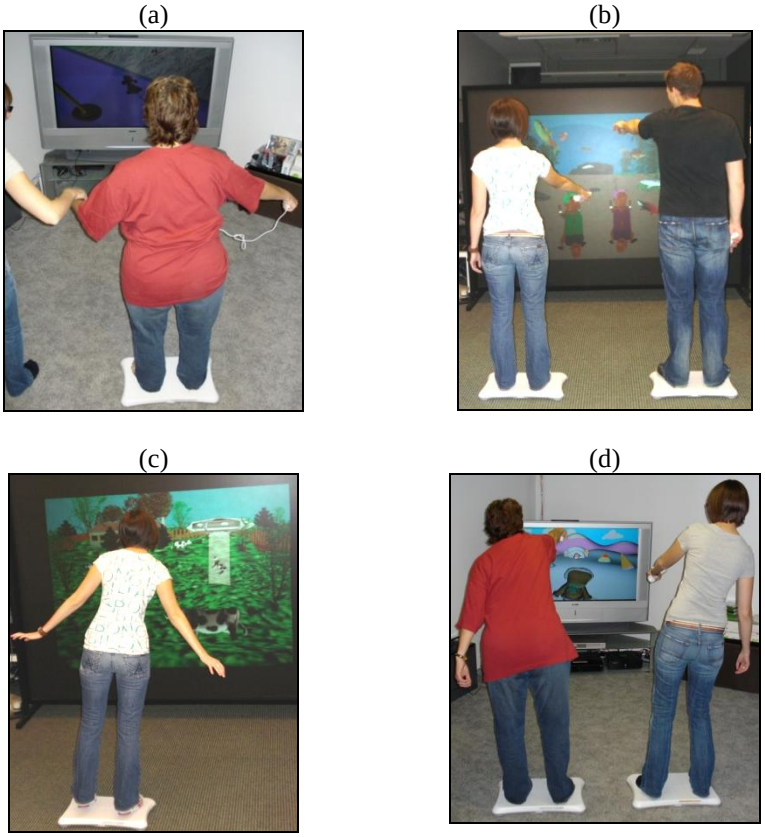

Figure 1: Patients interacting with: a) Mouse House, b) Startle Fish, c) Alien Invasion, d) Snowball Fight

In the Mouse House activity, the patient plays the role of a mouse that searches through a large virtual house to find pieces of cheese. In this activity, the patient uses a Wii Balance Board and a Wii Remote. The patient can sit on, stand on, or kneel on the Balance Board and use it as a navigation interface by shifting their weight to move the virtual mouse. This activity challenges the patient to exercise balance and movement precision. This activity can be played individually or with a partner. In partner mode, both players have their own Wii Balance Boards and view a split-screened virtual environment. In this mode, the players compete against each other to collect the pieces of cheese. This activity could be used to target or evaluate asymmetries in movement accuracy and trunk control.

In Startle Fish, the patient plays a diver and has to remain as still as possible to avoid being eaten by the virtual sharks. As the patients sway on the Wii Balance Board, they attract attention from the aquatic life surrounding them. If the patient moves their

center of gravity too much, the Wii Remote in the hand rumbles, and if a pre-determined movement threshold is exceeded, a shark eats the patient's character. The therapist can choose to make this a competitive activity by introducing a second player (who plays a second diver) and ask both players to outlast each other. Alternatively, players can be asked to spear as many aquatic animals with the Wii Remote as possible while still maintaining balance on the Wii Balance Board. The therapist can also change the magnitude and frequency of the visual, auditory, and haptic stimuli that are presented.

In the last activity, Alien Abduction, the patient is the leader of a group of aliens who want to abduct as many animals as possible. The game is set in an abandoned farm field that contains a number of farm animals. A patient must move their center of gravity to different sections of the Balance Board and keep balance in this position (for a predetermined duration) to 'beam' objects up to the spaceship. While an object is 'beaming' up, the Wii Remote in the patient's hand rumbles. If players do not remain steady on the Wii Balance Board, the object being 'beamed up' drops to the ground. This activity encourages patients to work on improving their static postural control, movement accuracy, balance, and lower extremity stability.

3. Conclusion

New methods of rehabilitation play a key role in restoring physical functions in an aging population. Current virtual reality-based rehabilitation and Nintendo 'Wiihabilitation' offer promising alternatives to traditional rehabilitation techniques, but both suffer from problems that prevent widespread adoption. We have presented a new system, Virtual Wiihab, which combines the flexibility of VR rehabilitation techniques with the availability and enjoyment of Wiihabilitation. Our system currently includes four rehabilitation-centric activities that demonstrate solutions to the problems that exist in the Wii and VR-based systems. The effectiveness and usefulness of the system is currently being evaluated in a local rehabilitation hospital.

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