Kinect-based virtual game for motor and cognitive rehabilitation: A pilot study for older adults

[Extended Abstract] *

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ABSTRACT

Physical rehabilitation is often necessary for individuals who suffer an injury or illness which causes a physical impairment, in order to restore movement and strength through supervised repetitive exercises. Alternatively, physical activity also improve cognitive performance and reduce cognitive decline. This tool focuses on therapeutic aspects of both cognitive and physical rehabilitation of older adults, that is, it improves the memory by performing mental activities and physical rehabilitation at the same time.

To achieve this, a Kinect based virtual game intended for Windows which enables users to control and interact intuitively with the computer without an intermediary controller has been developed. Furthermore, all the data generated during the session is stored in order to log every rehabilitation activity.

Preliminary tests have shown an increase in the users’ motivation while using the tool and it assessed the possible rehabilitation of 14 patients with motor impairments ($p < 0.05$) and the maintenance of their cognitive impairment avoiding its degradation.

Categories and Subject Descriptors
H.5.1 [Information Systems]: Multimedia Information Systems—Artificial, augmented, and virtual realities; H.5.2 [Information Systems]: User Interfaces—Input devices and strategies

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Motor, cognitive, rehabilitation, virtual game, Kinect, older adults

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1. INTRODUCTION

Many people suffer an injury or illness which causes a physical impairment such as structural deviations, mobility of bone and joint functions, muscle power or movement functions. These physical impairments can affect every structure and function of the body (as described by the WHO) and may hinder an individual’s ability to perform daily self-care activities. Consequently, this reduces their participation in the community and can significantly limit employment and educational activities [1].

Furthermore, physical rehabilitation is often necessary for these individuals in order to restore movement and strength through supervised repetitive exercises. In a standard medical practice in Spain, physiotherapists work with one patient at a time and monitors if their physical movements are reaching a specific standard, until the patient is able to regain an appropriate functioning. However, the number of exercises in a therapy session is relatively small [2]. A possible solution to this issue is the specialized personnel intervention, but it entails a high economic cost. Depending of the type of injury or condition the patient should follow an individual therapy regimen but the 33% of the patients do not perform the exercises as recommended. This can be due to several factors such as the lack of motivation or access to appropriate technological facilities [3].

In addition, individuals who suffer from brain injuries frequently acquire cognitive impairments, or thinking problems, that interfere with their safety and independence. The treatment method, known as cognitive rehabilitation, is designed to reduce cognitive dysfunction and/or assist individuals in compensating for its impact on daily living. The benefits of cognitive rehabilitation have been discussed in more than 700 published research studies [4].

Although larger and more detailed studies are needed, the research by Cay Anderson-Hanley et al. [5] suggests that simultaneous cognitive and physical exercise has greater potential for preventing cognitive decline, i.e., combining physical and mental exercise playing active games could have even more beneficial effects on cognition in older adults than normal exercise alone. Interactive physical and cognitive exercise over traditional exercise may garner added cognitive benefit, and perhaps prevent decline, all for the same exer-
exercise effort. Due to these reasons, the system described in this article focuses on therapeutic aspects of both cognitive and physical rehabilitation.

Here preliminary details of the Kineage rehabilitation system are provided; a Kinect based 3D serious game intended for Windows which enables users to control and interact intuitively with the computer without an intermediary controller has been developed. This virtual game will facilitate the physical rehabilitation of chronic patients and old or disabled people using virtual reality. Furthermore, it is specially oriented towards to work the cognitive stimulation in the language area as a priority and it has been designed to be used in therapies driven by clinicians. In order to achieve the rehabilitation part of the system, observations from psychologists and physiotherapists were taken into consideration. Serious games are an option to provide patients’ exercise combined with entertainment increasing their motivation [6].

2. MATERIALS AND METHODS
The proposed system uses Microsoft’s Kinect motion sensor connected to a PC, with an integrated database and video instructions to form the video game. Kinect is a webcam-style add-on for the Windows operating system, which provides a natural user interface (NUI) that allows users to interact intuitively and without any intermediary device, such as a game controller. It captures users’ full body movement in 3D virtual environment for interaction within game activities, that is, the user’s body is the game controller operating in 3D virtual space and multiple users can be tracked.

It is a sensor set on a horizontal bar with a small base, to be positioned below the video display. It has an RGB camera and a depth sensor, which provide full-body 3D motion capture capabilities. All this scans your body to identify your height and your movements. The tracking system of kinect has been evaluated successfully [7].

In this work, Microsoft Kinect SDK is used; an open-source library which can be used for testing and implementations. The Kinect sensor and its SDK provide a 3D virtual skeleton. This virtual skeleton consists of the positions of 20 joints and body parts (such as the wrists, knees, head and torso), and from here a 3D virtual avatar was generated. The joints that are used during the movement are mapped directly into the values placed on the avatar puppet within the game’s virtual world.

2.1 Participants
Fourteen users (9 women, 5 men) aged between 65 and 94 with an average age of 81.28 years (SD = 8.94) were recruited from Misericordia, a low-income nursing home for this study. This nursing home’s physiotherapists chose the participants with the following criteria: sufficient cognitive level to understand the game and the instructions from the physiotherapists and as physical conditions, to have a minimum movement in at least one of the arms. Two of them presented a visual deficit (presbyopia- age-associated eye condition) which presented sensitivity to light and one of them had age-related macular degeneration. Furthermore, two of them use wheelchairs for their daily tasks and another one had Parkinson’s disease.

2.2 Kineage Rehabilitation System
Firstly, and in order to do this rehabilitation system more generalized, it allows to specify the typology of the user, i.e., with or without any movement in their legs (use of the wheelchair), and giving the player the option to play standing or sitting. Additionally, users may present limited mobility in either arm (even absence of absolute movement in either of the two members), thus being the game configured in such a way that the user can choose if it wished to play with the left arm, right arm or both.

At the beginning of the game, the users will be asked to enter their name, which will be referenced in the scores, in order to store any information related during the game play. Then, the users have to calibrate the sensor in order to check their position in the settings option from the main menu. From this menu the user can select if he wants to play sited or not and which arm is going to play with.

For the skeletal system calibration, users must stand in front of the Kinect sensor about 1.5–2 meters away with their arms up and hold this position without moving for a few seconds. With this, the sensor gets a correct position of the user moving the device automatically up and down. This calibration method is predetermined for the sensor and the commercial games, which might not be appropriate for some users since might be unable to complete this procedure [8]. In this case, and in order to take the physical limitations of the users into account, a set of configuration options have been designed to make the game easier to play, such as the option of changing the angle of the camera (allowing the user to tilt the device up or down to get a better image or more complete view of the player) only moving one arm up and down. Additionally, the choice of a game-mode has been set up, that is, the user can chose how to control the game, with the left hand, the right hand, or both.

The Kineage system is divided into two sections: one dedicated to physical rehabilitation and another aimed at the cognitive one.

2.2.1 Physical Rehabilitation
The primary goal of this section is to perform physical rehabilitation exercises while playing having fun. This part of the game consist of three different levels in which the user should recognize various objects appearing on the screen by moving the arms, in order not to let the objects fall, promoting this way both the mobility of the user during the training and the cognitive process. The duration of each level can be adjusted by the physiotherapists to avoid fatigue in training. In the first level, the objects (cups and bottles of wine) shall follow a vertical path. In the second level the number of these objects increases and in the level three the objects follow a horizontal path. At the end of each one of the levels the user shall reach a piece of cake, until achieving as a final reward a whole cake after finishing the three levels.

This game is played in 3D virtual environment where the objects bottles of wine and cupcakes are falling to the floor. Every level has a different background picture of the environment. Players can see their individual arousal score indicated below, as well as the time remaining. In order to catch an object the player must do an arm movement to get
Figure 1: A user during the physical rehabilitation session

Additionally, different control parameters have been established such as the time per level, speed of the objects appearing on the screen, the quantity or the path they follow, in order to do different movements with the arms. Depending on the characteristics of each user, these parameters can be changed in the main menu, turning it into a slow-motion gameplay, helping users during difficult passages in it. If the configured settings do not provide the right amount of challenge (e.g. the patient makes faster progress than expected), the physiotherapist can adjust them easily for the next session. During the rehabilitation sessions, the system provides feedback (collected items, scores) as well as visual, auditory and textual feedback on the patient’s performance. After the session physiotherapists and patients can take a look at the data stored in the patient’s profile to determine the progress.

2.2.2 Cognitive Rehabilitation

The main objective of this section is to improve the memory and psychomotor activity by performing activities as well as they do physical exercise. The system specifically on the language area of the brain, which is mainly affected by people who suffer from dementia. Usually details related to remembering specific pieces of information such as the names of people or objects are forgotten by the patient. Due to the importance of the language area has, these mental exercises focus on the reasoning from word-classification activities using different semantic fields such as tools, kitchenware or furniture.

A range of exercises have been developed following the clinicians recommendations, in which the user must perform various physical motions in order to solve them. In this activities the user must to find items which can be stored in a supermarket, a stationery store or a pharmacy; or relate numbers with their corresponding definition (1-one), amongst others. Dementia is a progressive deterioration in cognitive function, so the application aims to adapt to individuals’ changing circumstances, if they become more cognitively impaired as they grow older, for instance.

Figure 2: A user during the cognitive rehabilitation session

All these exercises have been designed in a graphic way, in which the answers are images that appear on the screen. The objective is to choose the correct answers (images) moving the correct arm improving the psychomotor activity of the patient. See Figure 2.

The application’s objective is to reinforce the mental answers by having them be drilled into the user by doing motion controls. The iteration with the system is based on moving their arms. As in the physical rehabilitation part, the game can be configured depending on the cognitive state of each user adjusting the exposure time of the picture to memorize or the number of activities that will be performed.

2.3 Procedure

Permission to carry out the study was obtained from the home nursing and the IRB Committee. Participants provided prior informed consent written in Spanish (the participant’s natural language) and were approved by the IRB to participate in the study. The participants were informed explicitly, precisely and unequivocally of each step in the process, the consequences of obtaining the data and the purpose of collecting it. After this, they were asked to sign the consent form and complete a general survey form. Testing took place in the participants’ usual learning setting so performance in the study would be subject to the same environmental influences and distractions that prevail in the situation for which the system is intended.

2.3.1 Experimental Design

This game was used twice daily and a single subject multiple baseline design was used to evaluate the physical rehabilitation system effects with an ABAB sequence in which A is the no-intervention baseline phase and B the intervention phase. The effect of playing this game was examined using 14 subjects suffering from upper limbs impairments. Credibility was enhanced through the taping and recording of each session and through written observations.

In relation to the cognitive rehabilitation the participants’ cognitive impairment was measured before the intervention by the Mini Mental Status Examination (MMSE) ≥ 23 = Normal; 22-20 = Mild; 19-11 = Moderate; ≤ 10 = Severe. The average score for the 14 participants was 23.
2.3.2 Baseline
During the baseline the physiotherapist assigned the same exercise to each patient: raise the left and right arms more than 130 degrees 10 times. The number of correct movements in each session was counted manually by the physiotherapist.

2.3.3 Intervention
In this phase patients completed the third level of the game in which the pancakes and bottles of wine path is horizontal and objects move in the across the upper part of the screen simulating 130 degrees when raised the arms in order to collect them. As in the baseline phase, patients performed the exercise 10 times each one. The physiotherapist did not interfere during the rehabilitation session with the game and the number of correct movements was counted by the game when an object was collected.

3. RESULTS
Figure 3 illustrates the experimental design and the data obtained for one subject during the physical rehabilitation sessions. The baseline and intervention phases recorded the correct movements. The average in the first baseline was 10.4 and in the second baseline 10.3. During the intervention phases the average at the first phase was 21.1 and in the second one 21.4. A Kolmogorov-Smirnov test showed that the difference of results between baselines and intervention phases of the correct movements was significant ($p < 0.05$).

Preliminary results obtained from the cognitive rehabilitation part after doing the activities included in the game in relation with memory and language are encouraging even when a more longitudinal experiment is needed. After performing these activities twice daily during 80 days, the MMSE test showed again a result of 23 score for participants’ average.

4. CONCLUSIONS
This study assessed the effectiveness of this rehabilitation system which might facilitate autonomous physical rehabilitation prescribed by the physiotherapists. The results showed in this paper are related to one of the patients but the rest of the participants generated similar results. This pilot study did not show an improvement of the cognitive impairment measured by the MMSE, but the impairment is maintaining, that is, the cognitive performance is not declining and its progression is slow.

Preliminary tests has shown that the users motivation is increasing while doing rehabilitation and as the experts reported, individuals felt more relax doing this kind of activities. In addition, this tool can be adapted taken into account the mental and physical limitations of the users.

This system was developed in a first iteration to be played in a home nursing, but looking at the results authors think it is possible to aim this game at people who live independently at their home. In a future work researcher will include a monitoring module to assess the state of their patients and track their progress using a web platform. In this way, the patients’ data has not necessarily be accessed locally.

5. REFERENCES