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The design and evaluation of a peripheral device for use with a computer game intended for children with motor disabilities

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ABSTRACT

Many children with motor impairments cannot participate in games and jokes that contribute to their formation. Currently, commercial computer games there are few options of software and sufficiently flexible access devices to meet the needs of this group of children. In this study, a peripheral access device and a 3D computerized game that do not require the actions of dragging, clicking, or activating various keys at the same time were developed. The peripheral access device consists of a webcam and a supervisory system that processes the images. This method provides a field of action that can be adjusted to various types of motor impairments. To analyze the sensitivity of the commands, a virtual course was developed using the scenario of a path of straight lines and curves. A volunteer with good ability in virtual games performed a short training with the virtual course and, after 15 min of training, obtained similar results with a standard keyboard and the adapted peripheral device. A 3D game in the Amazon forest was developed using the Blender 3D tool. This free software was used to model the characters and scenarios. To evaluate the usability of the 3D game, the game was tested by 20 volunteers without motor impairments (group A) and 13 volunteers with severe motor limitations of the upper limbs (group B). All the volunteers (group A and B) could easily execute all the actions of the game using the adapted peripheral device. The majority positively evaluated the questions of usability and expressed their satisfaction. The computerized game coupled to the adapted device will offer the option of leisure and learning to people with severe motor impairments who previously lacked this possibility. It also provided equality in this activity to all the users.

1. Introduction

For children with motor deficiencies, participation in daily life activities, especially playing, guarantees that the brain and the body continue to be stimulated and active. Playing is the first productive activity of a child. The future competence of children is constructed by simulating the roles that they will later hold as a student, father/mother, doctor, police officer, driver, etc. [1]. Through games, children learn to act; their curiosity is stimulated; and they acquire initiative and self-confidence [1].

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However, when physical conditions limit exploration and manipulation activities, which are basic requirements for play, they can impede a special-needs child from developing the skills and attitudes that allow them to discover the world around them. These children in addition to being limited within their body, they are often not able to develop a healthy relationship with themselves, their family or society; therefore, they are confronted not only by their own limitations but also by the limitations in their interpersonal interactions, primarily in the pursuit of pleasure.

It is difficult to find a child who is not fascinated by contact with a computer [2]. Therefore, the computer can be a very useful tool in supporting the global development of children with severe motor disorders when used as an instrument for stimulation and communication. The computer can potentially serve as a therapeutic tool because computer use can combine functionality, pleasure, discovery, and autonomy.

In addition, computers have been used in combination with virtual environments for the rehabilitation of patients who have experienced cerebrovascular accidents [3]; simulated training [4,5]; the cognitive rehabilitation of patients with different types of mental health disorders [6,7]; providing leisure activities for the visually impaired [8]; and analyzing movements [9,10]. Another study [11] has demonstrated that virtual environments can play an important role in the treatment and training of individuals with disabilities.

However, accessibility and usability are essential for allowing users to completely realize the benefits of informatics. Usability is related to efficiency and user satisfaction [12]. Accessibility refers to not only the ability to reach a resource but also the potential for using a resource in a satisfactory manner [13]. Therefore, individuals with physical disabilities can only fully enjoy the benefits of informatics if peripheral devices are adapted to account for these individuals' limitations.

Certain authors have used webcams [14–17], Kinect [18], Wii [19] or Leap Motion [20] as tools for developing these types of peripheral devices. Webcams have been used as access devices that allow children with severe physical limitations to play 2D computer games [14]. Other authors [15,16] have sought to aid the rehabilitation of stroke victims by utilizing a webcam or augmented reality [21] in the development of a system and a 3D environment with increased levels of realism and immersion for players.

Several cameras were used for the recognition of all the movements of the hand [22], but computer access was only possible for children who had preserved hand movements. The Leap Motion is a revolution in the field of human–computer interaction, but due to irregular sampling frequency, it is not suitable as motion tracking system [20,23].

A depth-sensitive camera and a virtual environment were used to analyze the involvement of the pre-frontal cortex in equilibrium tasks [24,25] and for neuro-rehabilitation [26]. In another study [17], a webcam was also used for navigation of a 3D environment; however, the system was not developed for children with fine motor limitations, as it required precision in the movements. In another study [18], Kinect was used as a tool for rehabilitation; however, it did not permit interaction by people with fine motor limitations. Wii was used as a computer access tool [19]; however, the system requires precision in the activation of the console buttons.

To enable all individuals with physical limitations to enjoy computer-based entertainment, interfaces adapted to the requirements of each individual are required. In this sense, the need for interfaces that suit individuals' needs is evident [3]. Relevant requirements for achieving this objective include the ability to use an interface in real time and with precision.

In 3D environments, characters' movements must be triggered by rapid sequences of commands or keystrokes or by the use of complex, multi-level menus. These requirements require dexterity and precise movements. Consequently, children with severe upper-body motor limitations cannot effectively play certain computer games because the available systems associated with these games are insufficiently accessible to and usable by these children. Therefore, in this work, a 3D game triggered by a peripheral device adaptable to every need was developed. The peripheral device is composed of a webcam that allows players to control their characters' actions in a 3D environment, enabling children with upper-body motor limitations and children without these limitations to derive equal pleasure from the game in question.

2. Method

2.1. System design – peripheral device – game

The system was composed of a 3D game and a supervisory system that controls the character based on the images captured by a webcam. The 3D game was executed in a computer screen window (game window), and the supervisory system was executed on a second plane in a second window (control window). The user image, captured by the webcam, was shown in the control window (Fig. 1).

In control window three action regions were selected. Only the pixels within these regions were analyzed by the supervisory program. The other regions of this image served only as a reference. When a movement was filmed in one of these three regions, there were significant changes in the pixels of the region. The supervisory system analyzed which region exhibited a change and sends a command to the 3D game.

The three action regions selected to control the movements and actions of the game character were bounded by three squares. These squares could be positioned in any part of the image captured by the webcam. This system permitted adaptation as a function of the type and degree of motor impairment of the user. For example, for a user with only the articular amplitude of the fingers preserved, the squares could be placed side-by-side in the control window (Fig. 2A). In this case, if the user was positioned at the standard distance for computer use (45 cm from the webcam); he/she just needed to position the squares next to each other to control the character. For a user with tremors who was also 45 cm from the webcam, the squares could be positioned such that one was in the middle at the top of the control window, one was in the lower left corner, and one was in the lower right corner (Fig. 2B). Thus, the squares would not be activated by involuntary movements. In this manner, even a user with severe