ExerCaveRoom: A Technological Room for Supporting Gross and Fine motor Coordination of Children with Developmental Disorders

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ABSTRACT

This paper envisions a futuristic scenario for supporting gross and fine motor skills of children with developmental disorders in an integrated environment using virtual reality, exergames, tracking sensors (e.g., Kinect, Leap motion) and artificial intelligence. First, we show the importance of supporting gross and fine motor coordination skills of children with developmental disorders. Then, we state the technologies already developed and the current proposals for technologies designed for supporting gross and fine motor coordination skills. Our proposal consists of a technological room –*ExerCaveRoom*-, where children can practice exercises for fine and motor coordination skills specifically adapted for their needs using different kinds of technology, with the advantage of performing their complete therapy in the same environment. Additionally, the therapists can obtain children´s performance records to analyze their progress. Finally, we present the challenges involved in our proposal.

CCS Concepts

• **Human-centered computing → Accessibility → Accessibility technologies.**

Keywords

Children with developmental disorders; motor coordination skills, games; assistive technology; tracking sensors.

1. INTRODUCTION

Different developmental disorders are characterized by motor coordination problems including autism [11, 15, 20, 35, 38], dyspraxia [30, 33], and hyperactivity [3, 27, 32, 39]. The lack of motor coordination may restrict the acquisition and performance of other skills. In particular, gross and fine visual-motor coordination[1] may constrain the ability of individuals with motor problems to develop coordination skills appropriated for their age [15]. The deficit in gross visual-motor coordination can affect social skills, for example, children might decrease their interest to participate in team sports (e.g., soccer, baseball), affecting their ability to interact with their peers. In the same way, deficit in fine visual-motor coordination in children can affect them in the performance of their daily living activities, such as dressing, eating or bathing. Gross and fine visual-motor coordination skills are commonly used as a measurement of quality of life because they are critical for an individual's independence [25, 37]; therefore, it is important to provide support to improve these motor coordination skills.

To support children with a gross visual-motor coordination deficit, there are interventions consisting of physical therapies or motor training. Here, a therapist demands children to practice different gross visual-motor exercises while he/she provides a step-by-step guide. To support fine visual-motor coordination, children with developmental disorders attend to occupational therapy to perform activities that require fine motor coordination skills (e.g., insert small objects into a specific box area) [12, 14, 33]. Both, physical and occupational therapies involve the repetition of exercises or activities that can result boring for children with developmental disorders; as they might also have attention problems and a restricted range of interests [1]. These attention problems may result challenging for the therapists to get children´s attention and encourage them to practice the exercises or activities during the therapy session.

It has been demonstrated that Kinect-based games are a useful tool to support motor therapeutic interventions [23]. Using this technology can help to maintain the patients' engagement through multimedia and interactive content, while also providing the capability to track patients' movements. Another technology, with promising results, proposed to support motor therapeutic interventions is virtual reality [6, 31]. This technology can also facilitate patients' engagement in specific tasks, with the use of training scenarios able to adapt to the performance of each user, enabling with this an individualized training of graded difficulty and complexity. Also, recently, the use of the Leap motion sensor has been explored to support fine motor skills of stroke patients [13, 26], being this, a novel technological tool to support fine motor skills using augmented or virtual reality. In this paper, we propose a futuristic technological room that integrates these types of

[1] The ability to coordinate visual stimuli with body movements.

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technology along with machine learning techniques, with the goal of supporting gross and fine motor coordination skills of children with developmental disorders.

Using games for therapeutic purposes has different technological challenges [16, 22, 28, 29, 36]. One of them is the adaptation of the games according to the specific characteristics of the each patient, in terms of motor and cognitive performance. Particularly, children with developmental disorders have attention problems, so it could be difficult for them to stay focused on the motor task that the game is demanding, especially when the stimuli and reinforces of the game are not appropriate. The challenge here is to apply different adaptability mechanisms when the game detects that the patient is losing attention, such as changing the stimuli or providing positive reinforces. Another technological challenge is to assess the patients' motor performance in real time, without affecting the processing speed of the game. The motor assessment could be used to adapt the motor tasks according to each patient´s motor performance. In addition, the motor assessment could be used by therapists to monitor the progress of each patient. In this way, each therapy session will be personalized specifically to the patient´s needs, providing the best technological tools to support patients in achieving their motor therapeutic goals.

2. RELATED WORK

Different studies show the feasibility of using Kinect-based games in motor therapeutic interventions or motor training [2, 5, 7, 9, 21, 40]. For example, it has been proposed an exergame to support children with motor problems during motor therapeutic interventions [7] . This work shows how Kinect-based games can support the practicing of motor exercises of children with motor problems, and also demonstrates that the Kinect sensor is an appropriate input device for this population. However, the current proposals are not able to personalize and adapt to the needs of each child, where different kinds of information is considered, such as the movement of the body, the voice, facial expressions and where the attention of each child is focused.

In terms of virtual reality, different approaches have explored how virtual and augmented reality can be combined with the different tracking sensors to support motor skills rehabilitation of children with developmental disorders [8, 18, 19, 41], showing that this technology has the potential to be used to support traditional therapy techniques, as it maintains children' attention and engagement.

On the side of fine motor coordination skills, there is research dedicated to gesture recognition using Kinect [4], however, its use in supporting fine motor coordination skills during therapeutic interventions has not been fully explored. In this position paper, we propose to use the Leap motion sensor to support fine motor coordination skills. The Leap motion controller is a small sensor device, for gesture-based computer interaction, that supports hand and fingers motion as input. It can detect different hand gestures (e.g., reach out and swipe, grab, pinch, or punch) [42]. Different studies explore the use of the Leap motion sensor to support different areas such as children´s learning [13], sign language [34] and motor rehabilitation for stroke patients [24]. Studies of the use of the Leap motion sensor to support children with developmental disorders are scarce. For example, [17] presents a game using the Leap motion sensor to support motor rehabilitation of children with cerebral palsy. However, it focuses on an analysis of classification techniques on data gathered from the Leap Motion controller. The authors used decision tree models for developing a game aimed at support children with cerebral palsy. They conducted a usability testing of the game with volunteer students (no with patients with cerebral palsy), and present a demo of the game to physical therapists. The reviews of the students playing the game concluded that the interface was easy to use and that they could easily become proficient in using it. More research is needed to explore the use of the leap motion sensor in supporting fine motor coordination skills of children with developmental disorders.

3. EXERCAVEROOM

In this paper, we present a proposal of an interactive environment to support the therapies of children with motor coordination problems, assuming that the technological challenges previously mentioned have been overcome; for example the use of some machine learning techniques to properly adapt the games according to motor and cognitive performance of each patient. Also, we assume that the process of obtaining data from the tracking sensors, calculate the motor performance and adapt the game according to this motor assessment, is in real time, as well as, it is transparent to the patient.

Our proposal consists of an integrated technological room, that we call ExerCaveRoom, where a patient –a child with a developmental disorder- can play different games adapted to his/her needs in real time to support fine and gross motor coordination skills. The room is equipped with different tracking sensors such as Kinect and Leap motion, required to assess the motor performance of fine and gross motor skills. The computer where the games are running is embedded in the room, so that the patient has no access to it. Children can interact with the room via his/her body without invasive technologies like wearable sensors. The room is equipped with voice and vision recognition modules to recognize instructions and faces to personalize the therapy in real time. Each therapy session inside of the ExerCaveRoom consists of a personalized routine of exercises and activities to support specific areas of the motor coordination. For instance, there are games to support gross visual-motor coordination (i.e., the ability to coordinate movements with a visual stimulus), where the patient uses his /her arms to follow a pattern for helping a virtual dog to get home, connecting dots in the virtual scenario, as depicted in Figure 1.

Figure 1. An example of a game to support gross visual-motor coordination in the ExerCaveRoom.

The ExerCaveRoom also includes games to support fine motor coordination skills. For instance, a game where the patient has to execute the pincer grasp gesture (Figure 2) with his/her fingers to grasp a virtual object (e.g., a coin) and place it in a specific location (Figure 3).

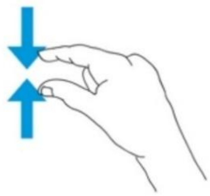

Figure 2. An example of the pincer grasp gesture required for playing some games to support fine motor coordination in the ExerCaveRoom.

At the beginning of the therapy session, the ExerCaveRoom detects automatically who is the patient and search for his/her history of motor and cognitive performance. Then, the system embedded in the ExerCaveRoom provides the most appropriate routine for the patient, which consist of a series of different games, according to the history of the patient and the recommended therapy. The routine is changing along the therapy session, according to the current patient's motor performance. The following scenario illustrates the use of the proposed motor coordination support environment.

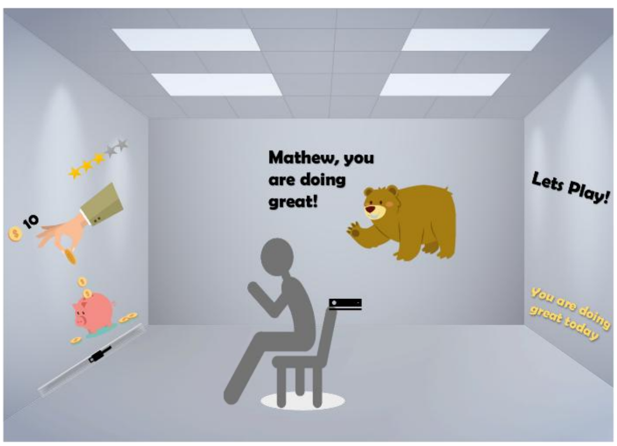

Figure 3. An example of a game to support fine visual-motor coordination in the ExerCaveRoom.

3.1 Scenario

Mathew is an 8-years old child diagnosed with hyperactivity and developmental coordination disorder. Mathew enters to the ExerCaveRoom accompanied by his therapist while a visual module automatically recognizes his face and retrieves his information from the database. The system rapidly setup a routine of games according to Mathew´s motor and cognitive skills and his preferences. As Mathew shows difficulties to move his left arm, the system prepares, among others, games specifically designed to improve his left arm movement. Additionally, Mathew has been showing fine motor coordination problems with his right hand, so the system prepares a routine to practice his fine motor coordination skills. The system examines Mathew's records and detects that Mathew has slightly improved his right fine motor coordination skills during the last days. Next, the ExerCaveRoom shows him games with minor changes that represent new challenges according to the recommendations for the occupational therapy. The system detects that Mathew is losing attention in the game, distracting or turning to look elsewhere, so the current game changes its stimuli according to Mathew´s preferences history (e.g., it shows Mathew´s favorite cartoon characters in a virtual way, and they talks with him to obtain his attention again). Mathew is focused on the game again, and he is performing the fine motor activities demanded by the game.

The ExerCaveRoom is designed to look like a house room, where Mathew feels comfortable and in a friendly environment. After he finishes 3 rounds of the game helping a dog (or other virtual animals) to get home (gross motor game from Figure 1), Sophie, his therapist, who has a mobile device connected to the ExerCaveRoom System, receives an alert about Mathew´s motor and cognitive performance, telling her that he had enough practice for the session, because Mathew starts losing his attention and gets tired, so she decides to change the activity. Mathew now goes to sit on a couch with a projection in front of him, and with the leap motion technology. The ExerCaveRoom system starts a game and invites him to play. The invitation can be through verbal and visual instructions, but in this case for Mathew, besides of the visual instructions, the invitation is through a particular sound that the system knows that calls his attention. The goal of the game is to put coins in a specific location (Figure 3), using the pincer grasp gesture with his fingers (Figure 2), where new challenges are introduced to Mathew according to his improvement. While Mathew plays, his therapist is receiving information in her mobile device where she can surf onto data, statistics and graphs that show the evolution of Mathew's motor and cognitive skills. Furthermore, Sophie introduces information and annotations to feed the system with her perception of Mathew's development. Finally, while Mathew leaves the ExerCaveRoom, the system sends to his therapist the record of the day and its proposals for next routines. After a few weeks, Sophie obtains different records of Mathew´s progress (including videos of him conducting the therapy, graphics with statistics in terms of attention span, the arc of movement, response time to a visual stimulus, etc.) using the ExerCaveRoom system to show Mathew´s progress to his parents. Additionally, the ExerCaveRoom system sends Mathew´s information progress transparently and automatically, to the medical rehabilitation doctor and the psychologist, who are part of the multidisciplinary team assigned to Mathew´s medical case.

3.2 Possibilities and implications

Having a therapy room as the one proposed, each child can have a specific routine therapy trying to get the best results in terms of motor coordination progress; and the therapist´s workload can be supported. With the assessment of the motor performance in real time, and by providing children the proper corrections about the execution of their movements in a friendly way (e.g., using their favorite superhero to provide the corrections), the therapist can focus on the children´s exercises execution. This allows that the therapist can stop making annotations of their motor performance constantly.

An implication of our proposal consists of the automatic recognition of the cognitive and motor performance during the therapy from each child, using different indicators like how much attention is paying through detecting facial expression or by recognizing their voice. Also it should be studied how integrate these feedbacks for designing new upcoming games adapted to the specific needs of each patient. The design of games can be based on an established methodology that fits with the suggestions from therapists, but it is necessary to conduct proper studies for understanding the values obtained by the tracking sensors and the annotations from therapists in order to properly integrate these data in motor therapeutic interventions.

The rich source of information collected from the tracking sensors and annotations from therapists can be used to analyze a more complete evolution of children, and to compare it with the performance of different children to propose proven successful exercises and activities. For example, if the system examines the most successful and unsuccessful routines for a child A, taking into account his/her specific characteristics, the system could propose routines for a child B (who has similar characteristics to child A) based on the knowledge, not only on the cognitive and motor performance of the child B, but on the evolution of child A, considering the routines that best worked for child A. The implications to achieve this are related to the current challenges in the big data field (e.g., integration of different sources of data, its standardization, analysis and storage) [10].

A possible advantage of our proposal is encouraging socialization between children with developmental disorders, as the room could be used by a group of children. Under this settings, games that need collaboration from more than one user can be designed. However, this leads to different challenges because the technology should be adapted for several users at the same time. This implicates the automatic recognition and tracking of each user.

4. FINAL REMARKS

Although different technology is already developed to support motor skills, currently there is not an integrated environment for conducting therapy to support both; gross and fine motor coordination skills. In this sense, we propose the ExerCaveRoom, which not only integrates the both type of therapies, but also it has the capability of automatic adaptation and personalization according to the specific needs of each patient. Despite many of the necessary technology exists, work should be done in the field of machine learning to properly adapt the therapy routines and inform the patient´s progress to therapists, doctors and parents. As well, studies should be conducted to understand the personalization and adaptation of motor therapies. We believe that the possible results obtained, worth the effort for the creation of this integrated environment.

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