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REVIEW

Application of augmented reality in physical rehabilitation

Aplicación de la realidad aumentada en la rehabilitación física

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ABSTRACT

Augmented reality (AR) has become a popular multidisciplinary research field in recent decades. Augmented reality adds to the subject's real-world sensory information through computer-generated sound, text, and graphics that are projected into the user's natural visual and auditory fields to provide a real-time interactive experience in a common environment. A bibliographic review was carried out with the objective of updating the current state of the use of augmented reality in physical rehabilitation. Augmented reality systems consist of a user interface that offers a motivational component to patients to perform exercises, distracting them from the potential pain they may feel during exercises. Additionally, they can be implemented in the patient's home and eliminate frequent visits to rehabilitation clinics. Among the most used systems are ARS, RehaBio, NeuroR, AR Fruit Ninja, MirrARbilitation, SleeveAR, ARIS and BRU. Its uses have been focused mainly on post-surgical orthopedic and neurological rehabilitation in patients with strokes. Augmented reality offers significant benefits over in-person rehabilitation and other technologies such as virtual reality, which can speed up the recovery process and improve patients' quality of life.

Keywords: Augmented Reality; Rehabilitation; Physiotherapy.

RESUMEN

La realidad aumentada (RA) se ha convertido en un campo de investigación multidisciplinario popular en las últimas décadas. La realidad aumentada se suma a la información sensorial del mundo real del sujeto a través de sonido, texto y gráficos generados por computadora que se proyectan en los campos visuales y auditivos naturales del usuario para brindar una experiencia interactiva en tiempo real en un entorno común.

Se realizó una revisión bibliográfica con el objetivo de actualizar el estado actual del uso de la realidad aumentada en la rehabilitación física. Los sistemas de realidad aumentada constan de una interfaz de usuario que ofrece un componente motivador a los pacientes para realizar ejercicios, distrayéndolos del dolor potencial que pueden sentir durante los ejercicios. Además, pueden implementarse en el hogar del paciente y eliminar las visitas frecuentes a las clínicas de rehabilitación. Entre los sistemas más utilizados se encuentran ARS, RehaBio, NeuroR, AR Fruit Ninja, MirrARbilitation, SleeveAR, ARIS y BRU. Sus usos se han enfocado principalmente a la rehabilitación ortopédica posquirúrgica y neurológica, en pacientes con accidentes cerebrovasculares. La realidad aumentada ofrece beneficios significativos con respecto a la rehabilitación presencial y otras tecnologías como la realidad virtual, que pueden acelerar el proceso de recuperación y mejorar la calidad de vida de los pacientes.

Palabras clave: Realidad Aumentada; Rehabilitación; Fisioterapia.

INTRODUCTION

Rehabilitation is a discipline that allows the recovery of a lost or diminished function of motor skills through a set of processes to return to routine or autonomous activities. The forms of rehabilitation can be physical, cognitive, sensory, practical, and often virtual, i.e., experienced in a technological environment, all of which aim to stimulate the mental functions necessary to recover motor movements.[1] Physical rehabilitation is the set of social, educational, and professional measures concerning the treatment of disability aimed at facilitating, maintaining, or restoring the highest degree of functional capacity and possible independence.[2]

Motor rehabilitation restores the patient's functional health, which is impaired due to deficiencies in the musculoskeletal or nervous system. Rehabilitation consists of iteratively repeating exercises to strengthen the affected area of the body. It requires performing movements in a very specific way. Otherwise, the benefits may not be adequate, and the desired results will be less noticeable.[3]

This area of medical science plays a key role in maximizing recovery and improving function to increase performance and autonomy in activities of daily living (ADLs) for both neurological and orthopedic patients.[4]

Two digital technologies can be used for virtual care services: virtual reality (VR) and augmented reality (AR). These can constitute complementary treatment tools for rehabilitation and physical therapy. The use of these technologies facilitates the performance of repetitive exercises and provides a mechanism to encourage patients through feedback.[5]

Augmented reality has become a popular multidisciplinary research field in recent decades. It has been used in different applications to enhance visual feedback for information systems. Faster computers, advanced cameras, and novel algorithms further motivate researchers to expand the application areas of AR.[6]

Unlike virtual reality, augmented reality augments the real-world environment rather than replacing it. Augmented reality adds to the subject's real-world sensory information through computer-generated sound, text, and graphics that are projected into the user's natural visual and auditory fields to provide a real-time interactive experience in a common environment.[1,7,8]

The augmented environment can be experienced through different sets of technology, including mobile displays (tablets and smartphone displays), computer monitors, head-mounted displays (HMDs), and projection systems that then lead to the development of spatial augmented reality (SAR). Recent technological advances have increased the popularity of AR among the public. AR enables a dynamic between users and real environments and, along with entertainment, to acquire useful information, e.g., how to take better care of their health.[6]

Virtual reality and augmented reality applications are transforming healthcare, medicine, rehabilitation, and patient education by providing new and innovative solutions to long-standing challenges.[9]

A literature review was conducted with the aim of updating the current status of the use of augmented reality in physical rehabilitation.

METHOD

A search for information was carried out in February 2024 in the databases Redalyc, Elsevier Science Direct, PubMed/Medline, and SciELO, as well as in the ClinicalKeys services and the Google Scholar search engine. Advanced search strategies were used to retrieve the information by structuring search formulas using the terms "augmented reality," "rehabilitation," "physiotherapy," etc., as well as their equivalents in English. From the resulting documents, we selected those that provided theoretical and empirical information on the application of augmented reality in rehabilitation in Spanish or English.

DEVELOPMENT

Motor rehabilitation occurs through regular meetings between the patient and physiotherapist with a frequency that depends on the availability of both. The time patients devote to therapy in clinics is very short compared to the potential time they can devote to it outside the clinical setting (e.g., at home). Often, since it must be performed over a long period, it is common for patients to become disinterested and, as a result, perform the exercises casually and incorrectly.[3,8] Therefore, it becomes crucial for the patient to perform exercises at home to accelerate the rehabilitation process. However, at home, both therapeutic instructions and corrections by the physical therapist should be provided verbally to the patient, potentially leading the patient to perform the exercises incorrectly.[3]

Rehabilitation systems should include repetitive, challenging, motivating, and intensive exercises to improve the effectiveness of patients' neural plasticity. Traditional rehabilitation methods are often performed with external instruments, such as treadmill ambulation using harness suspension and manual assistance by physical therapists, and arm-on-board skating that supports hand movement for upper extremity rehabilitation. Most traditional systems are presented to improve the performance of daily living activities and increase patient independence. However, these methods are increasingly expensive because they require individual therapist-patient activity.[8]

Rehabilitation therapies now include a variety of techniques and approaches that have enabled everything from specialized care for disabled patients to personalized therapy, which is becoming a leading public health strategy. Among these, a new category of rehabilitation systems and virtual environments for therapy has emerged, from telemedicine, alterations of user interfaces, and video game controllers to ¨serious games¨, virtual reality, and augmented reality.[10]

Interactive VR and AR systems can aid in the rehabilitation process. These systems consist of a user interface that provides a motivational component for patients to exercise, distracting them from the potential pain they may feel during exercise. In addition, they can be implemented in the patient's home and eliminate frequent visits to rehabilitation clinics.[3] Remote orthopedic rehabilitation is cost-saving for healthcare systems, demonstrated by reduced transportation, hospitalizations, and readmissions.[11]

In more recent years, AR and VR training systems combined with desktop computers and smartphone applications have been used as an adjunct to conventional rehabilitation. These technologies provide new opportunities to increase the sense of immersion in interactive applications, which can be combined with other game development techniques to increase user engagement, ultimately resulting in an improved overall experience.[12]

In AR, computer-generated graphics are superimposed on the user's real-world view, providing them with more information about the objects they are viewing. AR is generally provided through wearable-specific glasses, called smart glasses (e.g., Microsoft Hololens, Epson MOVERIO), or any device with a display and a camera, such as a tablet or smartphone.[12]

VR/AR technologies have great potential, as they can completely change the perception of the user's motor functions, potentially restructuring body proprioception, which is vital for neurorehabilitation, neuroplasticity, and general motor rehabilitation applications.[10]

AR can be used as a visual guide to perform an activity or to immerse oneself in a different environment. However, they can also be controlled by a variety of sensors or biosignals, where a natural body movement generates a response in the environment, which is displayed as movement or control of an avatar. A simple example would be to adapt the environment so that when subjects walk, it also moves, and they can explore it. Various rehabilitation strategies can emerge from these interactions.[10]

During the intervention, patients are guided and corrected by reliable and accurate feedback from virtual objects that AR accommodates to enhance motor learning and motivation. Interactive virtual objects created by AR in the real world induce more embodiment toward users than those created by VR in the virtual world.[8]

AR creates a safe environment that allows users to interact with real objects in real-world circumstances. Virtual reality and real reality overlap, and the patient is aware of potential dangers.[11] It is easily modified to accommodate the individual's disability or personal preferences. As AR technology becomes more accessible and affordable, AR interventions could be widely used in clinical rehabilitation settings.[8,11]

Personalized therapy is also within reach through AR, as these interfaces can adapt the level of complexity to the patient's performance and update as the patient improves his or her control over the affected limb.[10]

The AR systems used are varied: projectors connected to computers with webcams where images were displayed, virtual upper extremities, training videos, AR treatment with tablets, AR projections on treadmills or the floor, a head-mounted AR device used for holographic display of visual cues, and a newer system such as the 3D-RA system, in which the participant's body movement is tracked, creating an AR environment that generated real images captured in videos with virtual images.[13] The most commonly used augmented reality systems include:

ARS is also for post-stroke rehabilitation. Proportioning a motivating environment, based on a "butterfly catching" game, to perform reaching tasks. The authors presented two versions: a basic modality based on a computer game and a more advanced version that incorporates a control tool to increase the physical effort associated with the reaching tasks. In addition, it includes a game score.[4]

RehaBio can be used to restore lost upper extremity function in patients with hemiparesis due to stroke, traumatic brain injury, or spinal cord injury. The system includes three modules:

- a database to store patient profiles and training information
- a module for AR-based rehabilitation comprising four exercises (pin-pong rehabilitation, balloon-picking rehabilitation, object transfer rehabilitation, and animal feeding rehabilitation)
- a biofeedback simulation module to monitor and visualize the performance of trained muscles

The system includes user performance evaluation.[4,14]

NeuroR for post-stroke rehabilitation. This system provides motor imagery (which can be defined as "the mental execution of a movement without any overt movement or any peripheral activation") by means of a 3D virtual arm that replaces the paralyzed arm in a virtual avatar of the patient. It can be used both in rehabilitation centers and at home.[4,15]

AR Fruit Ninja is an AR version of the popular commercial game "Fruit Ninja" for chronic stroke patients. The game activity is displayed on a tabletop using a projector. When cutting virtual fruits, patients can directly observe the actual hand movement on the table. The system can provide feedback as the game scores to motivate patients during rehabilitation.[4,8]

MirrARbilitation is a system with gesture recognition based on markerless body tracking technology, such as the Kinect™ motion sensing input device from Microsoft®. The system guides and motivates the user during the execution of a reaching task, allowing the physical therapist to set the angle of the target object. It also provides points and instructions to avoid incorrect execution of movements. It is specifically designed to be adapted to a home environment.[4]

SleeveAR is a system that integrates multimodal feedback (visual-audio-haptic) to guide the patient through therapeutic rehabilitation exercises (abduction-adduction, elevation-depression, flexion-extension) prescribed by a physical therapist. The system provides the patient with movement guidance along with an exercise progress report via projections on his or her arm and the floor. Specifically, motion capture technology, such as Optitrack, is used to track the movement of people's arms. Sleeve is designed for home environments; however, because of its complexity and high cost, at this time, it may be used in rehabilitation gyms with multiple concurrent therapeutic sessions.[4,16]

ARIS (Augmented Reality-based Illusion System) was designed for clinical rehabilitation after stroke. The system uses computer vision technology to create an illusory environment and signal processing to monitor the performance of the trained muscles through an EMG (electromyography signal), as well as visual and auditory signals. The game consists of an exercise of circular movements focused on the shoulder joint.[4,17,18]

The Balance Rehabilitation Unit (BRU™) is a device that uses the transmission of virtual images viewed through 3D glasses to recreate situations that cause dizziness. It consists of a computer with software, a metal safety frame, a safety stand with handles and a belt, a force platform, virtual reality goggles, an accelerometer, and a foam cushion. It includes three modules: posturography, body balance rehabilitation, and postural training games. This system makes it possible to train different movements and oculomotor reflexes involved in maintaining body balance in a controlled manner by using a variety of visual stimuli modified according to frequency, depth perception, direction, and speed of movement.[19]

The combination of augmented reality and exercise may generate some psychological benefits, as well as an increased sense of energy and pleasure and a reduction in perceived fatigue levels.[19]

Some barriers limit the widespread use of AR, such as technological and user interface limitations. Other negative aspects, such as eye fatigue or human factors related to the effects of prolonged use, such as latency and user adaptation to the equipment, could also reduce task performance. In addition, depth perception may make objects appear more distant than they really are.[13]

It also appears that AR has not been used because, for the same goal, other technologies with simpler approaches, such as VR, can be used. However, augmented reality has advantages that virtual reality does not.[13]

The choice to develop an AR system for physical rehabilitation is based on the fact that automatic visualization during movement execution can improve the patient's body awareness, which can lead to more effective therapy, allowing activation of an additional visuospatial network of the cortex.[3]

Another benefit of AR for rehabilitation applications is exercise accuracy during interactive tasks. Comparative studies show that tasks performed with VR/AR for reaching activities showed more accurate routes when AR is used with more efficient exercise.[3]

The advantages of virtual reality, augmented reality, gamification, and telerehabilitation have already been demonstrated in various fields of medicine, but studies focused on orthopedic rehabilitation are still scarce.[11] To overcome the current drawbacks of AR and generalize it in the rehabilitation field, some prospects for future rehabilitation systems should be integrated with many modern technologies and devices, such as artificial intelligence and the Internet of Things, because these high technologies can intelligently adapt exercises based on users' progress and feedback. In addition, they can provide various interfaces, various training programs, higher precision monitoring, and higher quality of presence and embodiment for users. To increase user motivation during treatment, it is required to design engaging content for the AR system, but it is also necessary to design a system that is easy to use, portable, and low cost.[1,8,13]

Management and monitoring of users' health and progress should be implemented in AR rehabilitation systems. It is necessary to establish telerehabilitation that can monitor changes in activities and personal behavior in real-time during or after treatment and then communicate with healthcare professionals.[8]

CONCLUSIONS

Augmented reality has revolutionized the field of physical rehabilitation by offering an innovative and effective way to improve patient recovery. Healthcare professionals can now design personalized rehabilitation programs tailored to the specific needs of each individual. Augmented reality allows patients to perform exercises in an interactive and motivating way, which increases their engagement and persistence in the recovery process. It also provides real-time feedback to correct techniques and improve results. Overall, it offers significant benefits over face-to-face rehabilitation and other technologies, such as virtual reality, which can accelerate the recovery process and improve patients' quality of life.

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