Virtual Rehabilitation Platform for Left-Handed People Working in Industrial Environments

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Abstract. The left-handed people represent approximately 15% of the world's population, being a minority group, which has had to adapt to the use of objects designed for right-handed people. This phenomenon is also extrapolated to the industrial sector, where these persons is forced to make movements of force and coordination when using machinery not designed for them. This work proposes the implementation of a platform consisting of two sections: the first one uses the Edinburgh handedness inventory to determine the laterality degree of a person and the level of risk of physical injury. The second section implements a virtual rehabilitation routine, through a mini-game implemented in Unity and uses the Kinect game controller for motion capture. The platform aims to improve the quality of life of left-handed people working in the industrial sector, implementing an easy-to-use solution, which can be used at the business or personal level.

Keywords: Kinect · Edinburgh handedness inventory · Mini-games · Laterality · Rehabilitation software

1 Introduction

Currently, despite major technological changes, there are minority groups, such as left-handers, whose needs have not been met in a holistic manner. The degree of use of one side of the body over the other is known as laterality, and it determines how easily a person uses one side of his or her body to do activities that require the use of strength, precision or coordination [1]. In [2] a study of psychosocial differences between left-handed and right-handed children is presented, where it was determined that many objects used in everyday life are made to be used by right-handed people, for example: bottle caps, scissors, musical instruments, computer keyboards, tools, etc. According to

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Fisher [2], this causes left-handed people a mechanical and social difficulty from early ages, repeating the pattern until adulthood.

Left-handed people have had to adapt to the world of right-handed people, which can eventually lead to physical injury. In the industrial sector, for example, machines and tools are mostly designed for right-handed people. The use of the non-dominant side of the body to make movements of strength and coordination can cause from mild pain to severe injury depending on the person's level of laterality. This scenario represents a health risk for left-handed people working on right-handed machinery.

This work addresses this issue by implementing a web platform, which can be easily used by employers to determine the level of laterality of their workers and, if necessary, provide them with virtual rehabilitation therapy, without having to leave the company. Virtual rehabilitation has been widely tested and used in recent years, and many of these systems use Microsoft Kinect sensor as part of the solution. Kinect is an input device that has a depth camera to identify objects in three dimensions, incorporating several sensors that allow: motion detection, skeleton recognition and gesture detection [3]. There are several studies that use Kinect as an input device to solve problems in different areas, such as: cerebral palsy [4], rehabilitation of people who have suffered accidents and loss of motor skills [5], etc. Lun and Zhao [6] in their research on the applications of Kinect in topics related to human movement and recognition, show the impact of the interaction between users and game consoles.

On the other hand, rehabilitation for left-handed people who work with industrial machinery designed for right-handed people has been poorly explored, therefore, the implementation of our platform aims to be a new low-cost alternative that improves the quality of life of these people, safeguarding their health. The platform consists of two parts: the first is a web application that can be used by companies to keep track and evaluate the laterality of their employees, through the Edinburgh handedness inventory [7]. The application determines the level of risk of injury that a left-handed employee has when using machinery designed for right-handed people. When a person uses any of their limbs with equal ease to perform complex psychomotor activities, they are known as ambidextrous [8] and represent only 3.7% of the world's population.

The second part of the platform implements a mini-game, where the person is subjected to make movements with his right arm, which will act as a rehabilitation therapy session, but in a virtual way. Kinect will be used as an image input device, reading the movements of the person during the execution of the game and determining if she/he is correctly performing the movements previously loaded in the application. This part of the platform is intended to be used mostly by left-handed people, however, it could also be useful for right-handed or ambidextrous people, even though their risk of injury is minimal. The web platform is available in http://zacur.pythonanywhere.com/.

2 Materials and Methods

The platform was implemented with the use of various software and hardware tools, selected according to their technical characteristics and deployment and programming versatility. A systematic review of the literature, in the area of physiotherapy, has allowed the design of an appropriate rehabilitation exercise routine.

2.1 Platform Implementation

The application supports the creation of an account (session) that allows the administration of several individuals (employees), this implies, the registration of the personal information of each employee and the application of the Edinburgh handedness inventory to determine its laterality. The application was developed with Django 2.1 framework and Python 3.6 and uses a Model View Controller (MVC) architecture. The Edinburgh handedness inventory consists of ten questions, and according to the user's answers, it yields a quantitative value that determines the person's level of laterality. The scale of scores ranges from 30 to 50 points. There is a risk of injury if the result is greater than 35 points, as from this degree of laterality a person is considered to be left-handed [9].

On the other hand, although Kinect was initially conceived to be used in Xbox video game consoles, it has lately served as a low-cost input peripheral for medical research projects. For the development of the virtual rehabilitation module of our platform, Kinect v2 was used for its versatility of operation and accuracy in body movement recognition. Kinect v2 has a complete SDK that can be downloaded through the official Microsoft portal and Unity was used for the programming of the mini-game, due to its compatibility with Microsoft's development components. Unity has a personal license, which allows the free download of the application and its integration with Visual Studio, ergo; the scripts used to encode the video game are in C#. Figure 1 shows a block diagram summarizing the operation of our platform.

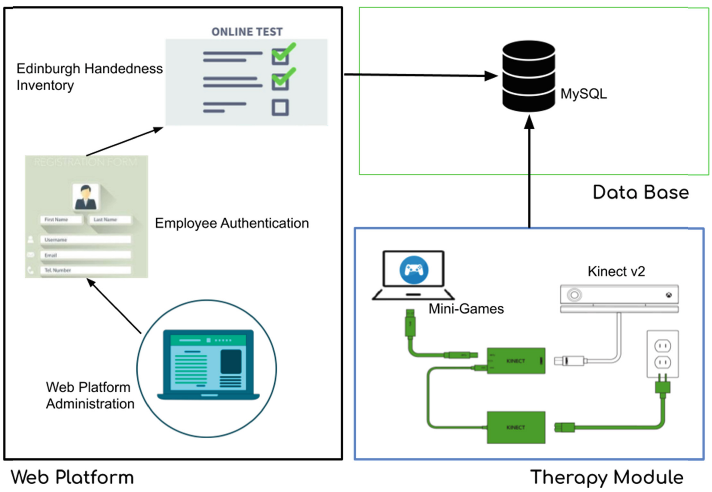

Fig. 1. General operation scheme of the platform

2.2 Therapy Rehabilitation Design

Shoulder injuries can occur from mishandling machinery or when machines are not designed for left-handed people. According to Donatelli et al. [10] this condition can lead to pain and limitation of wide movements, known as adhesive capsulitis, commonly called frozen shoulder. Treatment of frozen shoulder focuses on rehabilitation of the glenohumeral and scapulothoracic joints. The priority is to perform movements that include clavicular elevation, posterior axial rotation, internal rotation, upward rotation and external rotation. That is, the movements are concentrated on different angular rotations involving the humerus, scapula and clavicle joints, which are necessary to raise the arm [10].

Arthrokinetic movement refers to the movement that occurs on the surfaces of the joints. To restore movement to the shoulder in the event of injury, it is necessary for the muscles involved to be restored through exercises that rehabilitate their extensibility and balance. In addition, it is necessary to establish a therapy that involves applying movements to the tendons, with the purpose of releasing tension in the tissues. The movements can be low-load prolonged stretch, which aids in the extensibility of the glenohumeral capsule, and static progressive stretch, which consists of applying stress to the soft tissues, ligaments, and tendons of the shoulder joint [10]. According to [11], shoulder stretching improves the range of motion in the joints. This is because during stretching, the user tends to tolerate pain more and therefore makes increasingly wide movements.

The rehabilitation therapy proposed in our platform aims to work on stretching the muscles and tissues of the right shoulder to improve range of motion, when there are symptoms of pain or fatigue. For this, a mini-game with three sequential levels has been implemented, whose purpose is for the user to execute the stretching movements while playing. To complete each level the user has to obtain a minimum score or avoid a maximum number of failures, the approximate duration of the therapy is six minutes.

The first level of our mini-game, called “Destroy the ice blocks”, was designed to warm the shoulder and consists of moving the arm in different directions (arthrokinetic movements). In this level the user makes free movements to destroy pieces of ice appearing on the screen until obtaining 400 points, each destroyed ice add 5 points, which implies that the user must destroy 80 ices before moving on to the next level.

The second level, “Prevents the balloon from exploding”, works on static stretching. Static stretching is a type of stretching that involves bringing a joint to near the limit of its mobility and hold up this posture for a few seconds [12]. This level requires the user to keep his arm extended up or down for 30 s as shown in Fig. 2(A) and Fig. 2(B), to avoid explode a balloon. Three series must be executed and a maximum of five failures is allowed. If the user exceeds this value, she/he loses the level and must start the level again.

The third level works on the horizontal abduction of the arm over the posterior deltoid [12], this movement is achieved by extending the arm forward and moving it horizontally to prevent that a bouncing ball from across the screen, fall on the floor. The user have a one minute and during this time the ball is allowed to fall a total of 20 times (failures), otherwise the level must be repeated again. When performing this movement, the posterior shoulder area is stretched, as shown in Fig. 2(C) and Fig. 2(D).

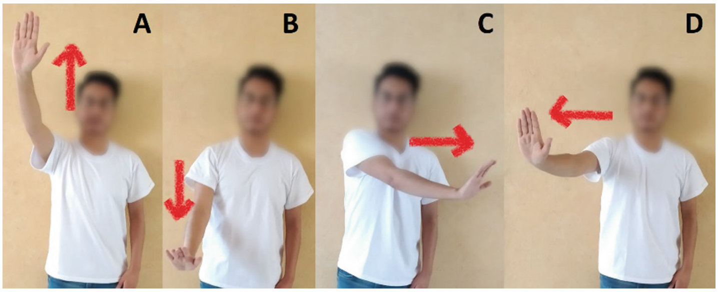

Fig. 2. Static vertical stretch (A) and (B), and horizontal abduction movement (C) and (D), performed while the user plays.

3 Results and Discussions

The evaluation of the tool aims to measure user satisfaction and usability of the platform. These measures was taken through user surveys (ten questions about the graphical interface, the usability of the platform, and the design of the mini-game levels) and field observation (to understand the management of the platform, degree of difficulty, therapy execution time, and number of failures). A sample of eight users was taken, who use the left arm for most daily activities and have experienced shoulder discomfort when using right-handed objects. The ages of the users for the tests range between 18 and 27 years.

First, the Edinburgh Handedness Inventory was applied to each user through the web application; the system gave information on the risk of shoulder injury according to the level of laterality, and presented recommendations to avoid such injury. Three groups of users were defined according to the level of risk of injury distributed as follows: low (63%), mild (12%) and high (25%). After the laterality evaluation stage, all users did a virtual rehabilitation therapy.

Figure 3, shows the average accumulated time game for each risk's level and the points indicate the general average duration of each level. The average duration of a complete routine was 5.6 min.

The user satisfaction survey also evaluates aspects of the graphical interface, usability, and well-being of the user while performing the requested movements in therapy. Table 1 summarizes relevant information about aspects of the graphical interface and the communication of the platform with the user through messages that are exposed during the session. In addition, Table 1 presents information on the muscular state of the user's shoulder after performing the therapy, taken into account sudden movements that could cause pain, natural movements that not forced, and ease of movements.

The overall usability evaluation average was 58.33% for the strongly agree category and 33.33% for the agree category, which represents that 91.66% of users were satisfied with the ease of use of the platform. Regarding muscle status after completing the therapy, the survey showed that, on average, 62.5% of users did not experience pain

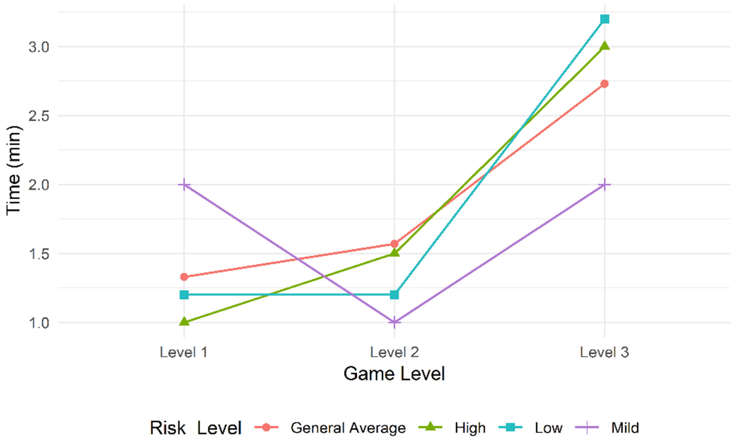

Fig. 3. Cumulative average time game for each risk level.

Table 1. Results of the survey after performing the therapy.

Aspect evaluated	Results (%)				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Easy to use	75.00	12.50	12.50	0.00	0.00
Graphics and interface	75.00	25.00	0.00	0.00	0.00
Game progress	25.00	62.50	0.00	0.00	12.50
General average	58.33	33.33	4.17	0.00	4.17
Natural movements	25.00	25.00	37.50	12.50	0.00
Ease of movement	25.00	50.00	25.00	0.00	0.00
Sudden movements	25.00	37.50	37.50	0.00	0.00
General average	25.00	37.50	33.33	4.17	0.00

or felt that the movements were forced. At the end of therapy, 33.3% of users felt muscle fatigue, and 4.17% were not satisfied with the movements programmed in the therapy.

After completing the tests, 75% of users assured that they would recommend the platform to be used in their workplace or use it personally. Besides, 91.66% of users accepted that the platform was easy to understand and that the information presented was sufficient to track the progress of their therapy.

4 Conclusions and Future Work

This work evidenced the importance of considering the needs of left-handed people and take advantage of technologic tools to mitigate the effects of using equipment not suitable for them. Also, we showed that virtual rehabilitation, through Kinect technology, is a valid option to build platforms that allow the evaluation, treatment, and monitoring of injuries caused by the use non ergonomics industrial equipment. Our platform proved effective when determining the degree of laterality, since 100% of left-handed users obtained laterality greater than 35. According to the results of the therapies performed, it can be shown that the playing times and number of failures were congruent for the three groups of people in which the sample was divided. That is, the therapy works correctly regardless of the level of laterality of the user.

As future work, we propose evaluate the effectiveness of the platform in the prevention and/or treatment of injuries expanding the sample of users and increasing the number of therapies per user. In addition, it is possible add more levels to the mini-game, consider new moves or increase the duration of each routine.

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