Prototype of a Shoulder and Elbow Occupational Health Care Exergame

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Abstract. The use of gaming in non-entertainment scenarios have impacted learning, therapy, exercising and training scenarios, among many others. In terms of occupational health care, it can provide motivation and monitoring, while complementing surveys and medical examinations. The success of the exercise depends on several factors, from understanding the guides, the demonstrations and its causes and consequences. Related works in this area have approached this problem with different type of games and motion tracking to boost engagement and the acquisition of data. This work presents the development of a shoulder and elbow exergame using motion capture as a complimentary tool to traditional means of occupational health care exercising. The presented solution in this project tracks the user upper limb to provide feedback that may help improve the exercising experience through charts that can be sent to a health care specialist.

Keywords: Data · Game · Tracking

1 Introduction

Upper-limb musculoskeletal disorders are rising among the global population caused by occupational work habits, such as stress, repetitive movements, excessive forces, sedentary and sports practices [1, 2], as a result the quality of life of nearly 15.3 % of the world's population is being affected [3].

A solution to this problem is exercising; however, this activity requires motivation which varies from person to person, affecting the rate of success. In occupational health, this activity may help reducing the risk of suffering from a musculoskeletal disorder and even though this should provide enough motivation to engage into active pauses and self-health care, they are not practice due to the repetitive movements, lack of feedback and motivation, poor or nonexistent interactive scenarios, and unclear guides and explanations [4] Virtual Reality (VR) can provide tools for overcoming these challenges by offering immersion and interaction features in computer generated worlds that allow the user to perform activities within a controlled environment where rewards, feedback and clear goals are presented and provide engagement to the player [5]. Through the interaction with a VR environment the user can be distracted from the main activity (exercising) which results in the performance of a desired action within a

C. Stephanidis (Ed.): HCII 2015 Posters, Part II, CCIS 529, pp. 467–472, 2015.
DOI: 10.1007/978-3-319-21383-5_78

treatment with an entertaining experience, an example of such application can be found in cases where the pain feeling is reduced as a consequence of the engagement in a game [6].

Given the ample development and evolution of affordable tracking devices ranging from electromechanical solutions with inertial sensors [7], image processing [8], myography [9], electro encephalographic signals [10], along with the trend of having more natural and accurate interactions [11], several developments can be found on the literature taking advantage of these technologies. Several exercising scenarios have benefited from exergaming in scenarios such as in stroke rehabilitation, autism children physiotherapy [12], and elderly care [13]. At a commercial level fitness exergames have been developed with the goal of providing interactive and engaging scenarios that allow enhancing the user's experience [14], without providing feedback on the accuracy of the movements, mainly focusing on the experience of having a good time.

In this paper, the authors present the development of an upper limb exergame focused on the shoulder and the elbow active pauses, joints required to perform several daily tasks. The process involved analyzing the upper limb and the active pauses so the movements could be programmed as game mechanics to provide engagement while monitoring their correct execution with non-invasive motion tracking.

2 Exergame Development

The game development required the characterization of the upper-limb, ranges of motion, common musculoskeletal disorders and their exercises. This process provides sufficient information for designing the game's formal, dynamic and dramatic elements within the chosen scenarios.

2.1 Upper Limb Analysis and Exergame Design

The upper-limb is composed of the shoulder (3 Degrees of Freedom (DOF)), the elbow (1 DOF) and the wrist (2 DOF), supported by the humerus, ulna and radius, these allow to perform flexion/extension and adduction/abduction rotations as presented in Fig. 1.

Daily activities involving choosing and grabbing objects require arm movements using the shoulder and the elbow, however, when affected the disorders involving the rotator cuff require abduction and internal/external rotations exercises while standing straight with the elbows horizontally aligned. During this activity the elbows must remain at a 90º angle without moving the shoulder from its position (Fig. 1). In the case of the elbow the exercise requires to hold both of them tight and close to the torso using an elastic band to provide resistance for the flexion/extension movements [15] (Fig. 1). These exercises are recommended to be performed o regular basis from a minute to five during working hours to help reduce the risk of musculoskeletal disorders.

With the information from the exercises and their required movements within the time constraints of occupational health the game is designed to provide a suitable active pause environment based on motion capture at a 1.3 m from the sensor. The interaction is setup to use gestures to encouraging the use of the upper limb and create familiarity

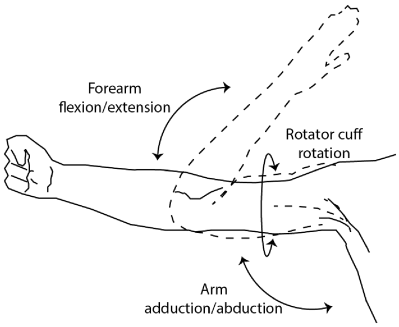

Fig. 1. Upper limb DOF and shoulder and elbow exercises

with the user interface. The game elements are defined as follows: the goal of the game is to provide entertaining active pauses for shoulder and elbow that feedback the player and a healthcare specialist with recorded motion data; the rules of the game are to reach the goal on each level, to accomplish them, the player is required to properly execute the movements and overcome the presented obstacles while gathering each level collectibles; the feedback is provided in terms of scores, motion graphs and on-screen tips about the importance of exercising.

On a general basis, the GUI allows choosing the menus, to pause, to continue and to exit of the application. During the game the user's movements are tracked using a Kinect to trigger the virtual characters actions and this data is saved to a chart that allows quantifying the experience and validate if the user is doing the exercises correctly or incorrectly so a healthcare specialist could do a closer follow up.

Two scenarios were implemented, a kayaking minigame for the shoulder and a snow skiing for the elbow, these were selected after a survey on which virtual environment would the user prefer; most of the participants expressed interest on scenarios not available to them which were also validated with healthcare specialists. The implementation followed the architecture presented in Fig. 2.

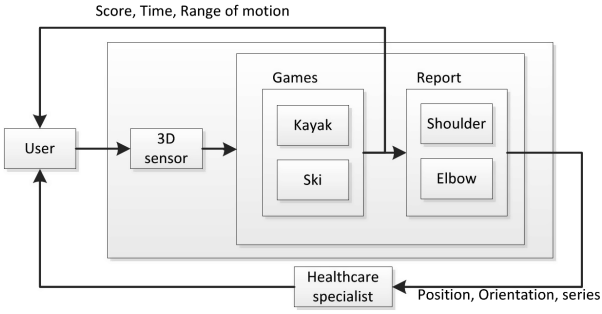

Fig. 2. System Architecture

For the development Unity and Microsoft's Kinect SDK were used. The scenarios modeled, textured, rigged and animated with 3D authoring software and then imported to Unity. Scripts were programmed to allow interactions and reactions accordingly to

the user inputs when using the menu and within the game, providing the feedback, scores, tips and penalties. At the end of the session the game show the collected data so the user or health care specialist can check the progression for performing corrective measures to improve the process.

3 Results

Two exergames for shoulder and elbow were developed, they provide scenarios where the player can practice active pauses in a kayaking and snow skiing virtual environment. Both games provide tips and motion data in graphics for assessing the progression. Figure 3 presents the developed games along with the user executing the movements.

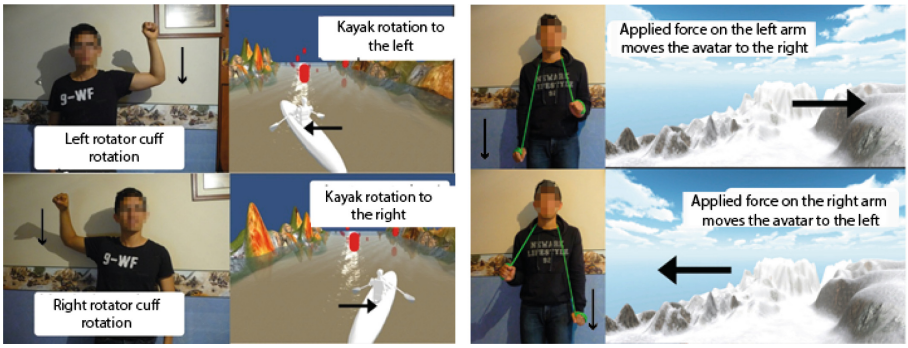

Fig. 3. Shoulder kayaking and elbow skiing exergames

To provide feedback both games indicate with red and green on-screen buttons if the motion was poorly or well executed respectively and if the mistakes occur three consecutive times a popup message appears reminding the player how the movement is performed.

To validate both exergames a survey was applied to 20 active computer users who use it for most of their work with the following results (Fig. 4 presents a player using the games at an occupational health care office): while 36 % acknowledge the importance of an upper-limb good health, 41 % said knowing some and 23 % expressed not knowing anything, among them, 82 % manifested rarely performing active pauses while 5 % did it every day and 14 % never engage in such activities. After presenting the game to the 20 interviewees, 77 % found it intuitive to use while 23 % disagreed, this occurred due to bad player tracking as a consequence of room lightning and player's clothing; 32 % found the healthcare information very useful, while 64 % found it normal due to previous knowledge and 5 % founded of little use; the popup messages when making mistakes during the game were found very appropriate by 94 % and 1 % found inadequate, for most of the users this was a result from tracking challenges which help them to improve the experience, however, it was also

found that the popup message caused distraction during the game. Finally, when asked if the game was motivational enough to using it continuously as an active pause complimentary too, 95 % declared that they would and 5 % stated that a game was not required as it was already a routine practice. The motion capture information was validated with healthcare specialists who after observing the data could identify if the motion ranges were within the expected, it is worth noting that there weren't any abnormalities detected on the collected data, however, the when the tracker failed, the information couldn't be assessed.

Fig. 4. Test at an occupational health care office

4 Conclusions

The development of exergames not only impact users with specific needs due to their conditions, but also impact people in other scenarios such as the practice of active pauses that may help preventing health risks. Due to its broad commercialization the Kinect is tool that participants manifest having or being interested into acquiring one due to its affordability. The quantification of the motion by providing feedback on how well the movements were performed interested all participants due to the possibility of quantifying the exercising activity. Health care specialists that participated were very interested as it could provide more information about the user so they could better assess the player's progression. Finally, the system was well accepted and thus, future works will be on improving data acquisition with possibly a Kinect 2 or wearable sensors, as it was a factor that affected the player's experience; improved visuals and more exercising scenarios.

Acknowledgements. The authors wish to thank the Mil. University Nueva Granada for their support on project ING-1545. Also thanks to the Virtual Reality Center along with Dr. Bibiana Moncayo and Dr. Claudia Robayo.

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