Hand VR Exergame for Occupational Health Care

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Abstract. The widespread use and ubiquity of mobile computing technologies such as smartphones, tablets, laptops and portable gaming consoles has led to an increase in musculoskeletal disorders due to overuse, bad posture, repetitive movements, fixed postures and physical de-conditioning caused by low muscular demands while using (and over-using) these devices. In this paper we present the development of a hand motion-based virtual reality-based exergame for occupational health purposes that allows the user to perform simple exercises using a cost-effective non-invasive motion capture device to help overcome and prevent some of the muskoloskeletal problems associated with the over-use of keyboards and mobile devices.

Keywords. Active pauses, musculoskeletal disorders,virtual reality

1. Introduction

The widespread use of mobile computing devices coupled with vast availability of wireless networks and information and communication technologies (ICTs) has impacted our society, changing how we perform several daily activities (work, banking, healthcare, entertainment, transportation, etc.). Despite the benefits these technologies offer, improper uses can lead to musculoskeletal disorders such as carpal tunnel (a condition affecting the arm and hand that causes numbness, tingling amongst other symptoms) which, in worst case scenarios requires surgery to correct [1]. Most of these devices have moved from working related activities to our private lives, further increasing the risk of suffering a health related disorder [2]. However, focus on addressing hand work-related problems remains dependent on annual medical examinations and exercise guides provided to employees which are endorsed only if the worker considers it appropriate to comply [3].

Musculoskeletal disorders are associated with the highest work absenteeism rates and are the leading cause in decreased quality of life [3]. The WHO acknowledges and promotes the inclusion of ICT to improve healthcare through its e-health initiative [3]. ICT growth has also led to the development of apps and multimedia-based applications to motivate employees into performing quick exercises referred to as actives pauses [4].

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However, the reliance on specialized hardware may challenge broader implementations and employee impact due to affordability, and ease of use and setup.

Furthermore, many employees perceive active pauses as an obligation and as something that they are responsible for on their own, often times by following printed and multimedia guides. Further complicating matters is the lack of expert follow-up and assessment that and thus limit any feedback provided to the employee. Given the widespread occurrence of musculoskeletal disorders and the issues associated with current methods to overcome them, the objective of this work is to design and implement a game-based virtual environment (an exergame), as a complementary tool that will allow users (employees) to perform several hand exercises while at work in a fun, engaging, and motivating manner.

2. System Development

The goal of the exergame is to capture hand movements of the user performing flexion and extension and transform them into suitable inputs to control an avatar within a goal-based virtual environment using game elements to increase user engagement. Hand motions are captured using a Leap Motion controller and compared to a reference (correct) motion, performed by an occupational health expert and also recorded with a Leap Motion controller (see Figure 1).

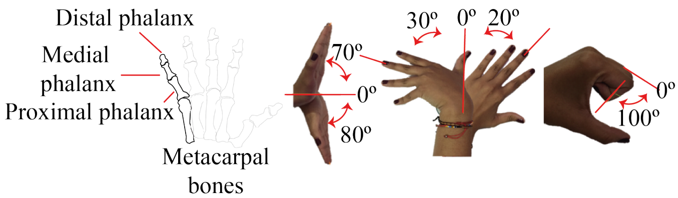


Figure 1. Human hand bones and movements

Occupational health exercises employ the movements presented in Figure 1 to help maintain healthy muscles, tendons and ligaments [5]. The goal of these exercises is to be performed in under five minutes. As movements are always the same, the virtual environment is designed to provide a creative form of interaction where users perform flexion and extension rotations to achieve a goal.

An analysis of current hand motion tracking solutions was conducted to determine the most adequate with respect to affordability, easy setup, and size. Several devices including those that employed haptics (5DT glove)[2], image processing (Kinect V2[3] and LeapMotion[4]), and exoskeletons (Dexmo[5] and Cybergrasp[6]). The LeapMotion was cho-

[2] www.5dt.com/?page_id=34
[3] www.microsoft.com/en-us/kinectforwindows/purchase/
[4] www.leapmotion.com/
[5] www.dextarobotics.com/products/dexmo
[6] www.cyberglovesystems.com/cybergrasp/

sen due to its small size, affordability, easy setup and integration (bundled with some laptops[7], keyboards and virtual reality headsets[8]).

2.1. *Motion Capture*

The LeapMotion is a device composed of three infra-red cameras that simultaneously tracks two hands using depth maps (the sensor has a detection area of $23.25cm^2$).. Although the Leap Motion SDK claims that bone, joint positions and orientations from each finger are captured, during our analysis we discovered that such measurements are estimated through a kinematics model and does not provide accurate data for finger movements.

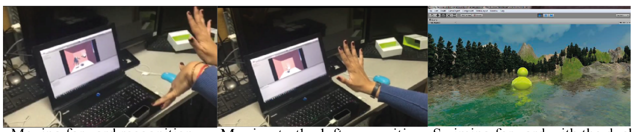
2.2. *Exergame Design*

The exergame is comprised of three key visual components (Figure 2), i) the lake environment, ii) the duck, and iii) the goal represented by a banner where the duck's mother is waiting. The objective is to swim across the lake and reach the goal by propelling the duck via flexion and extension hand rotations within a time limit. Swimming direction is linked to the player's movements whereby moving forward is accomplished from alternating hand movements and moving left or right requires a switch to the opposite hand. The range of motions are calculated according to the player's hand size, and the time limit is configured according to an expert's (i.e. a physiotherapist) recommendation.

Figure 2. Duck virtual character, scenario and integration

3. Results

The exergame records flexion and extension hand-based movements that were mapped to a swimming duck. Due to the sensor's characteristics, the ranges of motion were limited to a maximum of 50° with respect to flexion and 70° with respect to extension to ensure proper tracking and interactions. Finger tracking was not implemented due to the lack of accuracy that would have resulted in improper user interactions (this may have ultimately lead to reduced engagement and motivation).



Moving forward recognition — Moving to the left recognition — Swiming forward with the duck

Figure 3. Duck virtual character, scenario and integration

[7] `www8.hp.com/us/en/ads/envy-leap-motion/overview.html?jumpid=va_r11260_go_leapmotion`

[8] `http://store-us.leapmotion.com/`

The exergame was presented to a group of seven students working with computers in a Virtual Reality laboratory to gauge their perception of using games and motion tracking to promote healthcare. The participants were asked to start the exergame, explore the lake, and reach the goal. Preliminary results indicate that users found the exergame useful and believed motivate them to perform and complete their exercises. Participants also believed that the hardware was affordable and suitable for other applications.

4. Conclusions

Here we have presented a preliminary version of an exergame that offers users (employees) the opportunity to perform hand-based occupational health exercises in a simple, engaging, and fun manner. The exergame employs a Leap Motion controller to capture the user's hand movements and then compares them to a reference (correct) motion performed by an occupational health expert. The Leap Motion tracks movement one frame at a time alternating both hands not perceptible to human sight. If placed incorrectly or with direct light upon it, the resulting tracked data is not reliable and interactions are not possible. The device can provide suitable engaging interactions that in conjunction with a well designed game has the potential to promote awareness about hand healthcare.

Future work includes a larger scale user study to examine the effectiveness of the exergame with various scenarios and additional hand movements.

Acknowledgement

The authors acknowledge the support of Mil. Nueva Granada's Virtual Reality Center and the Social Sciences and Humanities Research Council of Canada in support of the IMMERSe network.

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