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A Virtual Reality Adaptive Exergame for the Enhancement of Physical Rehabilitation Using Social Facilitation

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Abstract

VR-based rehabilitation allows the creation of fully controlled environments that define training tasks specifically designed to target the individual needs of patients. VR-based rehabilitation systems can be integrated into game-like interactions, capitalizing on motivational factors that are essential for recovery [MP00]. This project focuses on the development and preliminary evaluation of a VR-based approach for upper limb rehabilitation in chronic stroke survivors who suffer from hemiplegia. Towards this end, we have developed a VR exergame, where the player is required to repeat the supination-pronation movement of the wrist joint, similar to that done within a physiotherapy session. An ongoing issue with such exercises in rehabilitation is that recovery methods lose their effectiveness when the procedure becomes tedious [KJ08, SLSORCan11]. Therefore, the application that we have developed differs from pre-existing ones in the fact that it is based on the theory of Social Facilitation [Z65]. The objective of the proposed project is to investigate the impact of the existence of a virtual agent on the patient's overall performance and interest in the upper limb rehabilitation exergame.

CCS Concepts

• ***Computing methodologies*** → Computer graphics; Graphics systems and interfaces; Virtual reality; • ***Social and professional topics*** → User characteristics; *People with disabilities*; • ***Hardware*** → Communication hardware, interfaces and storage; Sensors and actuators;

1. Introduction

This project focuses on the development of a virtual reality (VR) based approach for upper limb rehabilitation in chronic stroke survivors who suffer from hemiplegia. Classical kinesiotherapy requires repetitive and energetic movements that can become mentally exhausting for the patient. Recovery methods lose their effectiveness when the procedure becomes tedious [KJ08, SLSORCan11]. Exergames could solve this problem. We have developed an exergame, called FACE-UP, which is based on the theory of Social Facilitation, which argues that one's performance improves when one is in the presence of others or among others engaged in the same activity [BPL10]. Our aim is to create a flexible, personalized and adjustable environment for maximizing the performance of each patient.

2. The Application

FACE-UP concerns the repetitive supination - pronation movement of the affected forearm, relying on the repetitive task training approach [FTC*16]. The players should aim to charge the battery of a virtual car, by rotating (supination - pronation) their affected hand. The higher the degree of hand rotation, the more the cars are being charged (Fig 1). In FACE-UP, the patient can play the game alongside a virtual agent. At the end of each round, the cars are racing. The more each car is charged, the more their engine boost.

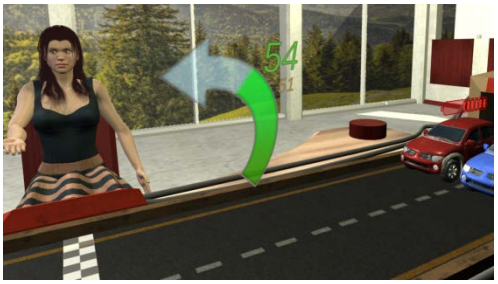

Figure 1: *The user interface provides graphical assistance for the rehabilitation exercise.*

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FACE-UP provides the ability to create any number of agents and customize their game behavior and appearance (Fig 2). Their performance can be set as dynamically adjusted to the performance of each patient, to keep the patient engrossed. This setting adapts at real-time the perfomance of the virtual agent according to the actual performance of the user.

FACE-UP offers moreover the capability to add more indoor environments, outside views, game modes and a virtual crowd. It would be interesting to study these factors and their impact on rehabilitation effectiveness. This application tracks the performance of the patient and collects data that can be useful for the patient and the health professional.

The patient's performance and motion data in each rehabilitation session are collected and are available to the patient and the health professional. This data could be very helpful for tracking the rehabilitation process.

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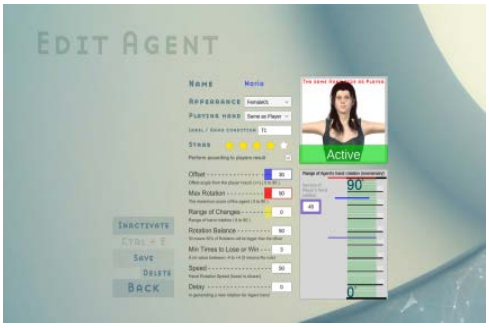

Figure 2: *The set-up of the virtual agent's performance specifications.*

2.1 Technical Setup

FACE-UP requires a PC equipped with an NVidia GeForce GTX 1060 graphics card (or higher) and 16 GB RAM (or higher), an Oculus Rift (CV1) head-mounted display (HMD), and an Xsens Wireless Motion Tracker (MTw) for the hand tracking. FACE-UP was created using the Unity (version 2019.2.8f1) software and the environment using Autodesk 3D studio Max and Adobe Photoshop. The virtual characters were designed by Reallusion character creator and animated with Adobe Mixamo.

3. Proposed Study

One of the main features of FACE-UP is the inclusion of customizable virtual agents that are playing the game alongside the patient (Fig 3). The main aim of the study to investigate the impact of the virtual agent's performance, which can dynamically change at run time, on the patients rehabilitation effectiveness in relation to each patient's individual characteristics.

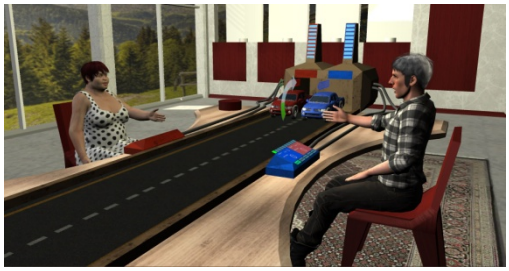

Figure 3: *The game environment with a virtual agent.*

Therefore, an alternating Treatment Design with three conditions will be applied. In the first condition (T1), the virtual agent is set to perform better in most attempts than the participant. Conversely, in the second condition (T2) the virtual agent is set to perform worse than the participant, in most attempts. T0 signifies the absence of an agent. The amount of hand movement repetitions required per session is determined by proven stroke recovery practices [BPL10]. The data will be gathered via the application metrics, self-report questionnaires, and motor assessment instruments and will later be analyzed.

4. Future Work

The findings of the proposed project will direct further the development of a VR application that may improve rehabilitative care of stroke survivors in the future and contribute towards guidelines for the use of social facilitation in the development of other VR systems used in rehabilitation. Furthermore, specific parameters such as the level of presence and embodiment and their impact on rehabilitation effectiveness can be furthered examined.

5. Acknowledgments

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