Social Assistive Robot for Cardiac Rehabilitation: A Pilot Study with Patients with Angioplasty

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ABSTRACT

Socially Assistive Robots (SAR) have been gaining significant attention in multiple health care applications. However, SAR has not been fully explored in cardiac rehabilitation (CR). One of the most critical issues in CR is the lack of adherence of patients to the rehabilitation process. Hence, based on the evidence that the presence of an embodied agent increases compliance, we present in this paper the integration of a social robot in a CR programme. The setup is evaluated with four patients divided into two conditions (robot and no robot), in order to evaluate its first four sessions as a preliminary study. The results show that this system might have a positive impact on CR and holds promise to be extended to a larger group of patients.

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1 INTRODUCTION

Over the past years, socially assistive robots (SAR) have been gaining significant attention in multiple healthcare applications. Different types of SAR agents have been introduced in rehabilitation scenarios, such as post-stroke rehabilitation [1] and pediatric rehabilitation [4]. However, SAR has not been fully explored in cardiac rehabilitation (CR), which is the medically supervised therapy for patients who suffered a cardiovascular event. According to the literature, initially, SAR was aimed at supporting nurses during therapy and to address staffing shortages in CR. In [2] a "hands-off" physical therapy assistant, CLARA, was developed, aimed at helping patients in repetitive and painful spirometry exercises. However, this study was run with healthy subjects and the authors of the paper state that no clinical studies were conducted.

One of the most critical issues in CR programs is the lack of adherence of the patients to the rehabilitation process. However, there is evidence that people can be more compliant and increase adherence due to the presence of an embodied agent [5]. For this reason, this work focuses on the integration of a SAR agent in a CR programme, augmenting a sensor interface developed in earlier work [3]. The setup (see Fig 1) integrates a heart rate monitor, a Laser Range Finder (LRF) sensor to estimate the gait parameters, and an Inertial Measurement Unit (IMU) sensor to measure the treadmill inclination. In addition, a social robot (NAO, SoftBank Robotics Europe, France) is used to interact with the patient, providing motivation, monitoring his/her condition and providing feedback during the session. The interaction with the robot is facilitated by a tablet with a graphical user interface (GUI). This paper presents a preliminary study for a group of four patients, in order to evaluate the performance of the system, the compliance of the patients and the level of human-robot interaction.

Figure 1: Experimental setup at Fundación Cardioinfantil

2 HUMAN-ROBOT INTERFACE

According to the clinical staff involved in the project, the system should address two main aspects of the therapy. (1) Motivation: during the session the patients receive feedback and motivation from

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the medical staff. (2) Risk factors: cardiac arrhythmia, unexpected increasing of the heart rate, dizziness, extreme fatigue, pain, and falls can compromise the health and safety of the patient during the exercise.

The developed system measures three types of variables selected by the medical staff for monitoring the patient's status during the therapy: **cardiopulmonary parameters**: peak heart rate, heart rate variability and evolution of heart rate using a wireless heart rate sensor Zephyr HxM BT (Medtronic, USA), **gait spatiotemportal parameters**: cadence, step length and speed performed by a laser range finder LRF Hokuyo urg-04lx-ug01 (HOKUYO, Japan) and **parameters of physical activity intensity**: Borg Scale (BS) asked by the robot and the tablet each three minutes. The BS is delivered to the system by means of the GUI, which provides the parameter feedback as well. Finally, the treadmill's inclination is measured with an inertial measurement unit (MPU9150, InvenSense, USA).

The robot is placed on the side of the treadmill, below the eye level of the patient. Once the therapy begins, the robot stands in order to draw the attention of the patient and starts the interaction (see Fig 1). The sensor suite provides the robot with the data in real-time enabling the robot to respond to the patient's performance and status. The robot's behavior can be classified into three states:

Motivation: the robot provides motivation to the patient by saying something amusing or encouraging to increase or maintain motivation, every 5 minutes.

Warning: when any of the aforementioned risk factors is perceived, the robot enters the warning state. The most important risk factor to control is the unexpected increase in the heart rate. Once an increment of this parameter is perceived, the robot asks the patient whether everything is fine or medical staff should be called. If the patient reports that everything is going well, the therapy continues normally. However, if the response is negative or a response is lacking, the robot changes to the **Emergency** state. Another risk factor that is controlled in this state is dizziness and the possibility of falling. To avoid this issue, the robot monitors the patient's posture with a camera and asks the patient to correct the posture.

Emergency: this state is triggered when the existence of a risk factor is confirmed and can be set in three different scenarios: (1) when the warning state changes to the emergency state; (2) when the robot detects an excessive increase in heart rate, and (3) when the alarm is triggered by the patient through the GUI (pain, dizziness or fatigue). The robot alerts the medical staff while indicating the type of the emergency.

3 EVALUATION

Four patients were divided into two groups (No robot condition (NRoC) and Robot Condition (RoC)) in order to compare the first 4 sessions of each patient in a preliminary study. Three metrics were considered for the evaluation of the therapy: response time, heart rate recovery and motivation. The **response time** measures how compliant the patient is to a request for reporting the BS value, which corresponds to the time between the system request of BS and input time from the patient in seconds. **Heart rate recovery** measures the evolution of the heart rate (BPM) during the first minute of the cool-down phase. The **motivation** of the patient is acquired at the end of the session, through a Likert scale (0 to 10, 0 not motivated at all and 10 very motivated) with "How was the session today?" and "How motivated do you feel to come back?".

4 DISCUSSION

Although the number of patients in each condition is limited, this work serves as a pilot study to provide a first view on the ability of the system to provide reliable information and to analyze the interaction between the users and the system. During the experiment, we observed that patients in the RoC scenario seem to be more compliant with the requests that the robot made along the sessions compared to patients in the NRoC condition. Results show an average response time of 12 seconds in RoC, while for NRoC this was 28 seconds. This is a positive aspect that shows promise for an embodied agent within the sessions. It was also possible to observe that the system is able to assess some of the aforementioned risk factors and make effective interventions to reduce them. On the other hand, there was no observable pattern in the heart rate recovery between two scenarios. However, in the long-term experiments this metric might be significant in order to compare how well patients improve their physical condition on each scenario. According to the third metric described above, the motivation results from all patients was 10 for both questions, indicating that all of them had felt very well during the sessions and are motivated to come back. Since all the results are the same, it is not possible to carry out any comparison between the two scenarios.

5 CONCLUSIONS

This work presented the integration of a SAR agent into the CR therapy by means of a sensor suite enabling a robot to have access to the parameters relevant to the session and to control its behavior. We also presented metrics relevant to the therapy and the robot behavior. The next step that is proposed is to extend the experiment to a larger number of patients with a higher number of sessions.

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