Study of a Smart Cup for Home Monitoring of the Arm and Hand of Stroke Patients

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ABSTRACT

In this work, we present a platform for continuously monitor and guide stroke patient at home during Activities of the Daily Living. The platform consists of a smart cup which embeds sensors that monitor the patient's hand and arm motor activity at different times of the day. The cup detects its orientation, the liquid level, its position on a specific target, as well as tremors. Moreover, displays are provided to guide the patient's movement. Finally, the planned studies with both the therapists and patients are presented.

Keywords

Stroke; Monitoring; Home; Cup; Internet of Things

1. INTRODUCTION

15 million people are affected by stroke every year. Stroke patients encounter varied cognitive and motor impairments [3]. Stroke rehabilitation is very expensive in terms of infrastructures and medical staff. Moreover, patients are left alone at home without monitoring to assess their recovery. Usually, recovery progress are evaluated before each rehabilitation session by the therapist with empirical measures based on visual estimations [4]. Yet, many Activities of the Daily Living (ADLs) can provide relevant data about the patients' recovery [2]. The emergence of Internet of Things let us imagine to perform continuous monitoring of stroke patients at home. The collected data would allow the therapist to adapt the rehabilitation program according to the patients' progress. This paper presents the design and implementation of a smart cup, called SyMPATHy, based on a common ADL: filling a cup and drinking. It aims to monitor the arm and hand activity of stroke patients and to provide a gestural guidance during recovery exercises.

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2. CONCEPT

The design process of SyMPATHy includes five main steps and is based on the following methodology:

1 Identification

- Task to perform (see Section 2.1)
- Information to monitor (see Section 2.2)
- Sensory feedback to provide to the patient (see Section 2.2)

2 Implementation of the platform (see Section 2.3)

3 Data acquisition and processing (see Section 2.3)

4 Technical study of the platform (see Section 2.3)

5 Planned studies (see Section 3)

2.1 Task to perform

According to interviews with two qualified health professionals working at a stroke rehabilitation center, the work focused on the task of reaching, filling and transporting a cup. This task is based on different motor sub-tasks (arm movement, hand grasping, etc.) with the upper limb which is involved in other usual ADLs (cleaning, take a shower, etc.). Moreover, it simultaneously involves vision, tactile, proprioception and audio sensory feedback.

2.2 Features and feedback design

Drinking and filling task is composed of different steps which required monitoring: (1) Filling the cup, (2) Grasping the cup, (3) Holding and moving the cup and (4) Releasing the cup on the table. In addition to the monitoring, providing feedback is essential especially for patients with motor and sensory impairments. Alert and guidance during filling and drinking steps enhance the performances and motivations of the patients [5]. The visual feedback was preferred for step 1 (filling the cup). Informal study led us to use the visual channel by displaying colors vertically along the cup. Liquid level information is simplified by discrete colors chosen according to the European culture (red, orange, yellow and green). The selected feedback for the third step (hold and move the cup) is a visual feedback around the top of the cup. The LEDs display colors according to the inclination of the cup (green 0-20°, yellow 20-35°, orange 35-50° and red $> 50°$). Furthermore, the audio channel is used to alert the patient when he reaches a spatial target on the table. This allows to unload the visual channel. No sensory feedback was provided for the grasping and tremors data.

2.3 Implementation

SyMPATHy embeds a Raspberry Pi Zero and sensors which retrieve and process data in order to provide the correct feedback to the patient. Orientation detection is supported by the 9-DoF Inertial Movement Unit (IMU) MPU-9150. Industrial liquid level sensors having constraints (size, low-reactivity), a custom liquid level sensor based on liquid conductivity and tension divider bridges was added to the cup. For each level, an electrode is wired to a tension divider bridge. Measuring a tension allow to detect the presence or absence of liquid. The relative position to a given spatial target is assessed by a Near-Field Communication (NFC) Reader. Finally, Force Sensing Resistors (FSR) have been added to the grooves on the hand print in order to monitor the force applied on the cup while grasping.

A technological study have shown that the gyroscopic tremor detection is reliable with a error range of 3.6% and match the data-sheet of the IMU sensor which forecast an error range of 3%.

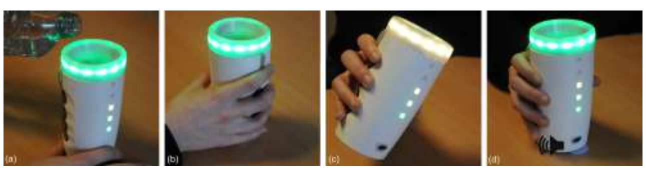

Figure 1: SyMPATHy cup used during steps: (a) filling, (b) grasping, (c) moving and (d) releasing.

3. PLANNED STUDIES

Based in this first SyMPATHy prototype, two series of studies are planned with both therapists and patients. The first goal is to retrieve feedback in order to improve the design and the technical features of the cup. The usability and acceptability of the platform will be also investigated. Finally, the impact of the device on the patients' health state should be assessed. The first study will be conducted with therapists in order to improve the cup. Then, a second study will be carried out with real patients to assess acceptability.

3.1 Study with therapists

The SyMPATHy cup provides a large number of relevant data on patient's activity (temporal records, mean values, 3D gestures, etc.). The collected data has to be displayed in order to provide usable information to therapists. A study with therapists working in a rehabilitation center will be carried out to provide understandable information and usable visualization tools. This study should highlight the most relevant information to display as well as the way to display it. The resulting recommendations should help us to upgrade the visualization interface on the basis of therapists needs. More fundamentally, the study will address the usefulness of the data of such type of platform to monitor the daily living activity of patient.

3.2 Study with patients

Another study with real patients in a rehabilitation center must be carried out. The aim of this study is to assess the acceptability of the cup in the rehabilitation process. The evaluation will be gradual. First, the smart cup (features, recorded data and displays) will be presented to the patients. Then, patients will be asked to use the cup without providing feedback. Afterwards, the sensory feedback will be enabled. During each step, the acceptability and the usability of the device will be investigated with both the patient and the therapist. The results of this study should highlight the features to improve and allow us to identify the weaknesses which could lead to the rejection of this technological concept [1].

4. CONCLUSIONS

SyMPATHy smart cup prototype have been developed for monitoring and guiding stroke patients during ADLs. Data collected provide relevant information about the patient recovery state and the therapist can adapt the rehabilitation program. Two studies are planned to improve the features of the cup as well as create a usable visualization tool for the therapist and investigate the usability of the cup both for patients and therapists.

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