Smart Rehabilitation Garment design for arm-hand training

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ABSTRACT
This paper describes the design of a smart rehabilitation garment (SRG) to support posture correction during rehabilitation training. The garment is equipped with accelerometers in various positions and is controlled by an Arduino processor. It connects with Bluetooth to a smartphones or a personal computer in order to provide feedback to patients. The garment provides reminders to users by vibration. We discuss the placement of sensing modules, the garment design and the integration of smart textiles and wearable electronics.

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Design, Human Factors
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Wearable technology, Arm-hand rehabilitation, Smart Garment design, Smart textiles

1. INTRODUCTION
Stroke is a major cause of acquired adult disability[1], which reduces the quality of living and the independence of stroke survivors. As the population is aging there is a need to support rehabilitation training with technology in order to provide more efficient and effective therapy, and to support patients reach their full potential for recovery.

Technology can support training through providing interactive exercises and even games, designed to help the patient practice tasks improve their strength and control. See for example [2], [3]. Due to the long time recovery process, the prospect of using such technologies at home offers the promise of cost-efficiency and of increase in the amount of training, which can in turn improve training outcomes. However, stroke patients who have a reduced capability to control their arm-hand, tend to develop compensatory strategies where they use alternative movements and muscle groups to compensate for the diminished capability of their damaged arm. Applying such compensatory strategies during training reduces the training effectiveness. Currently training with or without technology often relies on therapist supervision, with the therapist reminding the patient to keep the right posture, and providing corrective feedback when the patient moves outside a specific range. This observation suggests the potential utility of posture monitoring and feedback technology that can be used within or outside the context of a specific game. For example, Timmermans et al used sensors on the arm and torso of stroke patients during training with the Philips stroke exerciser [4], in order to ensure the correct execution of exercise. Beursgens et al, developed a vest for monitoring the patient posture while playing a serious game intended to support arm-hand rehabilitation[5], [6]. These systems suggest how wearable sensor technology can be used; here we look to make a device that can be used in many different training approaches, that is not embedded in a specific game or exercise system. Further, we look to improve the engineering and design qualities of this smart rehabilitation garment.

Paralleling the advances in wearable application in rehabilitation, a number of SRG’s aiming at support arm-hand training have been developed [7], [8]. Although wearable technology shows great promise and provides many technical benefits in these systems [9], other aspects like the wearablety, the user experience and the aesthetics are often neglected[10].

In this research, we set out to design an SRG with integrated smart textiles and wearable electronics for encouraging patients’ posture monitoring in the context of home rehabilitation. Smart textiles have become a dominant trend in wearable electronics[10], especially healthcare with the features like: washable, flexible and lightweight, follow current style trends and enhance the user’s experience.

2. System concept and requirements
We propose a monitoring system that aims to improve motor
training quality by sensing the compensation movement with shoulder and torso. While wearing the garment during rehabilitation exercises, the user can set a goal range. When the detected compensation movement is over the set value, user can get vibration feedback.

Following the guidance from therapist and earlier investigations from Annick Timmermans et al [6], [11], we identified the design of the garment system for arm-hand rehabilitation should consider the following requirements for both the function and user experience aspects:

- Easily put on and off and worn with normal clothes.
- It should be light, comfortable and appropriate for long term monitoring.
- Make sure the sensors are always close to user’s body for the data accuracy.
- Provide feedback for monitoring result and system’s functioning.
- Be scalable for other modular functions.
- Be adjustable for different size.

Currently our prototype system consists of two parts: a smart sensing jacket and an app on smart phone controls the system also provides graphical feedback. The sensor position is shown in “Fig 1”, two accelerometers (S1, S2) are placed on the T1 and T5 of spinal column for monitor trunk movement [12]. While the other one placed on the shoulder of the patients affected side (S3 or S4).

3. Prototype and Architecture

We propose a modular design consisting in multiple sets of garments and one set wearable sensors. Based on the removable design of the wearable electronics, users can have not only one choice during their rehabilitation exercise at home. The sensing garment should look friendly and familiar and offer better engagement.

3.1 Components in detail

The system contains three sensor nodes that communicate to two Lilypad Arduinos. The sensor comprises the following components:

- 3 LilyPad Accelerometer ADXL335 sensing unit,
- 2 LilyPad Arduino 328 Main Board as the central node read sensor data from the 3 accelerometer separately,
- a small and inconspicuous LilyPad Power Supply with input battery from 1.2v-5v,
- a Bluetooth Mate Silver module for wireless communication between the jacket and smartphone,
- LilyPad Vibe Board embedded closed to the accelerometer provide vibration feedback.

3.2 Garment design

The garment, shown in “Fig 3”, is designed in “front” and “back” parts for ensuring the accurate sensor position and measurement. Based on the adjustable design on shoulder and wrists, the garment can fit multiple sizes of people and keeps the sensors close to users’ body and at the right location.

3.3 Conductive textiles integration

Conductive textiles in health care garment applications show a great potential. Using them to make wearables for home-based rehabilitation can help users who wear them feel more free and monitoring posture all day. In this system, a conductive network was applied to enhance the aesthetics of the design without adding the original resistances. We designed conductive fabric pattern for the removable design of wearable sensor and conductive path for the connection between the electronic modules, shown in “Fig 4” and “Fig 5”. The sensors can connect to the garment by attached.
snaps. Furthermore, as the cut pieces are small and needs to be an exact match, laser cutter is effective for this process.

4. Future work
In the future we will develop the system in following steps:

- The implementation of data processing, signal analysis like signal filter to pre-process data and multi-channel data fusion will be conducted to eliminate noise from the system.
- The software interface design, enhancing the graphical feedback and providing historical training datasheet.
- Carrying on preliminary evaluation of the garment.

5. Conclusion
We set out to design a garment as a platform for arm-hand rehabilitation research. We have proposed a design of the smart rehabilitation garment system, providing feedback of compensation movement to improve users’ correct execution of exercise. The integration of smart textiles design to wearable projects contributes to implement the reliable and comfortable monitoring system. The system can be used in different context and training approaches and the adjustable design ensures the sensors stay in right positions. Due to the modular and cost-effective design, the system has a good potential that achieves both accuracy and comfort.

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7. REFERENCES