A Prototype of an RFID-Based Command Sleeve With Changeable Microcircuits

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***Abstract*— This this study presents the initial prototype of a command sleeve designed to assist in pre-determined daily tasks and communication of those who have co-morbidities in terms of both speech and motor skills. The command sleeve is based on passive RFID tag design featuring a magnetic microcircuit attachment mechanism, for quick change and customizable assistance in varying situations. The command sleeve has two embroidered dipole antennas and altogether four microcircuits with magnet mechanisms. Testing on a human body demonstrated read ranges of around 150 cm for all antenna and microcircuit combinations. The findings suggest that there is potential in integrating magnet-based changeable microcircuits to passive UHF RFID technology, despite possible challenges in tag performance, which will be the focus of the next study.**

Keywords*— *assistive technology, changeable microcircuits, Design Thinking, magnets, passive UHF RFID, smart clothing

I. Introduction

Assistive Technology (AT) is an umbrella term for all technologies aiding and enabling the user to function during daily living [1]. Although there is a wide array of assistive technologies available, only a small minority of them adequately meet the needs of their users. In addition, ATs are often regarded as extensions of the body [1], [2], leading to relatively high expectations regarding their performance. In their current form, many assistive tools tend to stigmatize the user [2], [3]. For achieving greater user acceptance, designers have adopted Design Thinking approach, which seeks holistic user understanding for desirable, viable and feasible results [4], [5]: The design process is non-linear, iterative, and achieves the outcomes by emphasizing, defining the research problem, ideating, prototyping, and testing [6].

In terms of AT, smart clothing has been predicted to resolve global and burdening challenges related to health and rehabilitation [7]-[9] but it still remains a marginalized AT solution for severely disabled individuals and for those with co-morbidities, such as difficulties with fine motor skills and communication. The cumulative functional limitations of these individuals often render the majority of available ATs unsuitable, highlighting the urgent need for customizable innovations tailored to users' needs and preferences.

Passive ultra-high frequency (UHF) radio frequency identification (RFID), then, has an extensive potential to be impeded to assistive clothing. By connecting RFID tags to mobile phones, the application possibilities become virtually limitless. The basic components of an RFID system are the reader with an antenna, software, and a tag with an antenna [10]. In a passive system, the tag antenna harvests the energy from signals emitted by the reader antenna. Furthermore, passive tags typically consist of electrically conductive material, and microcircuit (IC), which are usually integrated permanently to each other [11], [12].

Nevertheless, separating the IC from the conductive antenna offers several benefits, such as 1) ability to change stored commands/information 2) possibility to reduce the information flow caused by the detachment of the microcircuit and the antenna 3) chance repair the tag if the IC component itself is damaged. Even the separated microcircuits exist, to our knowledge, there are not microcircuits with quick-change opportunity suitable for clothing. Moreover, magnets in passive tags have been used to create contactless, coupling between the antenna and microcircuit on a flexible substrate such as paper [13]-[15].

Recent studies [16], [17] have proposed concepts for aiding speech with e-fabric pieces or with smart cloths and have presented user interfaces activated by tapping. [18] introduced the AACloth, which utilized passive RFID, with activation caused by covering the cloth with palm. Further, [19] has introduced a user interface constructed with passive UHF RFID technology. In addition, [20] detailed how to use passive UHF RFID tags to make a notification to a nurse's phone and [21] showed how to cause a phone call without fine motor skills. The nature-inspired textile-based passive tags aimed for appealing looks [22], and in [23] punch-needled tags seem to offer a tactile user interface if needed. However, the emphasis in these studies is primarily on RFID technology rather than the user.

Passive UHF RFID has been used as an activation button in previous studies: [24] created a push-button by 3D printing and separating the IC part from the antenna, while [25] presented textile patches activated by covering a fabricated bag with a palm, eliminating the need for fine motor skills. In addition, [26] made a textile-based passive UHF RFID music-player. [21], [22], [26] shows how passive UHF RFID tags

This work was supported by the personal grant from Jenny and Antti Wihuri Foundation (Tiina Vuohijoki) and the Academy of Finland (decision 332168).

and their microcircuit identifiers (IDs) can be turned as input in any application, this study focuses on fabricating the hardware around the microcircuit to cause controlled activation.

This work originates to focus groups introduced in [16], [25], where the focus was on possibilities of textile-based communication aids. Based on those research findings, unofficial multidisclipinary discussions were kept, and the idea of a command sleeve came together.

II. DESIGN AND FABRICATION

A. Emphatizing, Defining and Ideating

The user needs, and the general requirements for the sleeve prototype were defined in multidisciplinary ideation discussions, as shown in Table 1. In this context, the user is defined as “a person with co-morbidities affecting speech and motor skills; a person who is willing to participate in everyday activities in any way possible”. Then, the user needs were emphasized by health care professionals based on experiences in practical work life. The experts who gave their views during the discussions were a speech therapist, a nurse, an occupational therapist, and a physiotherapist. Professionals in electronics gave their technical support while ideation. The results of these discussions were aligned with the research findings from [16], [17], where textile-based ATs were activated by slapping or touching a specific spot. Also, in [18], Wireless Communication Textile patches were activated by placing the hand on top of a patch to activate a predefined spoken word from a mobile application. In other words, the operational logic should be quite simple.

Many ways to actualize this prototype exists, however, passive UHF RFID technology was chosen due to its passive nature, simple structure, and low-energy consumption. Additionally, connecting RFID tags to a mobile phone opens endless opportunities for creating applications to assist with daily living and communication. It was agreed that the prototype would be a sleeve, which could be connected to mobile phone for application purposes, following the activation method used in earlier studies [20], [25], [26] in which the passive tag was covered with a palm, and as the signal between the reader antenna and the tag is broken, the change in information flow is a sign for activation, in these earlier studies sending message, or playing pre-determined voice.

TABLE I. THE DEFINED REQUIREMENTS FOR THE COMMAND SLEEVE

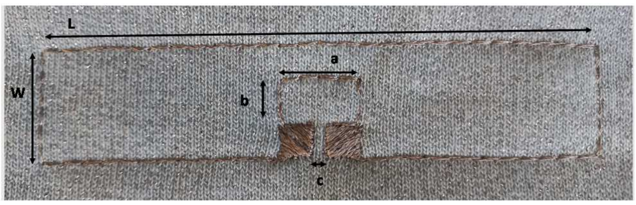
In terms of	***Requirements for prototype***
User needs	An interface usable without fine motor skills
	Visible markers indicating the command spots
	Audible “yes” and “no” answers
	Audible location request
	Music player activation
General requirements	No batteries or cords
	Clothy looking, perhaps a sleeve
	Should be customizable
	Only one output for each command

In this prototype creation altogether four kinds of activation were defined: "yes," "no," "location request," and "music player activation", and this information would be written into their own microcircuits. To avoid the potential complexity, each microcircuit had only one activation purpose. One option would be to fabricate all four tags to sleeve are, however, it was decided, that if too many activators were available once, the sleeve might be too complex to use. Customization for different situations would be achieved by changing the IC part of the designed tags.

Conventionally, the electronics in smart clothing are integrated with varietal techniques such as creating extra-folds or pockets, Snap-On -buttons, Velcros’ (either conductive or non-conductive), or magnets [27]-[31]. However, the first three mentioned were not suitable for design purposes due to concerns about visibility, clumsiness, or avoidance of extra folds. On the other hand, exploring the use of magnets seemed promising, especially from the user’s perspective: the user does not need to pay attention while targeting the chip with exact antenna location, but the magnet pairs define and guide to desired IC placement.

B. Fabricating the Prototype

For this prototype, a typical dipole antenna, widely used and studied, was chosen [32]-[35]. The antenna geometry is given in Fig. 1. First, an average sleeve shape was cut from cotton jersey, and the conductive antenna parts were embroidered onto sleeve with Bernina B500 Embroidery Machine. Conductive thread from Shieldex (silver coated nylon, 2ply) [36] was used for the upper thread, while common viscose embroidery thread was used for the lower thread. For this fabric and stitch combination, the upper thread tension was set to 2.75, the stitch length was set to 4 mm, and double run was used. Double run means that the machine first topstitches the full contour, then comes back along the same route resulting in double stitching. The asset in double run compared to the double outlining, backstitching, or satin stitching is that the thread is led from start to end with less bending, curving and tight forging, all of which can be related to higher resistance. After embroidering the contour, beddings for microcircuit copper pad integration were embroidered with diagonal stitching (see Fig 1).



Measures of RFID antenna				
L 100 mm	W 20 mm	a 14,3 mm	b 8,125	c 2 mm

Fig. 1. The used antenna geometry

Fig. 2. Four embroidered outputmarkers according to user needs (Table 1)

Next, the symbols indicating the pre-defined outputs were embroidered according to Table 1. The words "yes" and "no", the symbols for "location" and a pair of notes for music player activation were chosen (see Fig 2). The embroidering was done on white cotton fabric, using rayon embroidery threads (100 % viscose). The upper thread stitch tension was set again to 2.75, and a stabilizer Cotton Soft was used. Thereafter, one mini-magnet (neodymium magnets NdFeB, 4 mm x 1 mm) under each antenna bedding was sewn, (see Fig 3, top). Other, matching magnets, were glued onto backsides of the IC's with copper pads [37], finally the output marker was glued to magnets (see Fig. 3, middle).

Fig. 3. Changeable IC+magnet structure: first, a magnet pair was stitched by hand onto antenna bedding (top); second, the other magnet pair was glued to IC and to output marker (middle); last, the IC+magnet pair was placed to antenna embroidered to sleeve (bottom).

C. Testing Wireless Performance

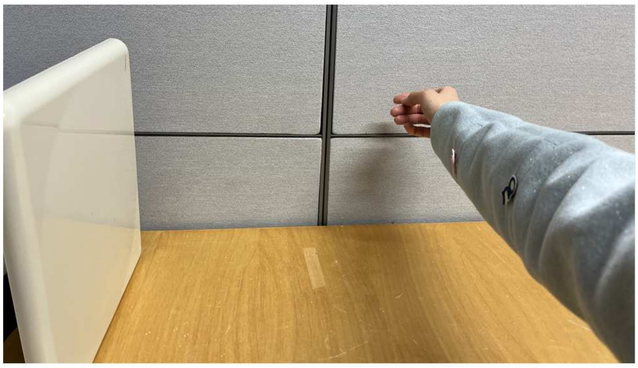


Fig. 4. Direction for radiation exposure. The sleeve was dressed on and arm held extended while exposed to radiation. Both dipole antennas are in upright position.

The wireless evaluation was conducted in office settings including typical office furniture such as desks, curtains, chairs, and computers. We measured the read ranges of both antennas with different combinations of IC's when sleeve was dressed on human. The measures were taken with Mercury6 measurements system and with ThingMagic software. The circularly polarized reader antenna, M6 and laptop was connected to each other with cables. The measurement setting is presented in Fig 4. We used only European frequencies (865.6–867.6 MHz) with a 28 dBm power exposure, beginning the measures from a 65 cm distance from the reader (from the direction visualized in Fig. 4). As seen in Fig 4, the tags were not fully straight, and had a slight bending while measuring, to note, a cotton shirt was worn under the command sleeve.

III. RESULTS

A wireless command sleeve for people with multiple limiting conditions was created (Fig 5). The sleeve has two embroidered antennas (Fig 5.) In addition, four changeable IC+magnet structures were constructed. The attained read ranges varied between 1 meter and almost two meters. All results from practical measurements are presented in Table II.

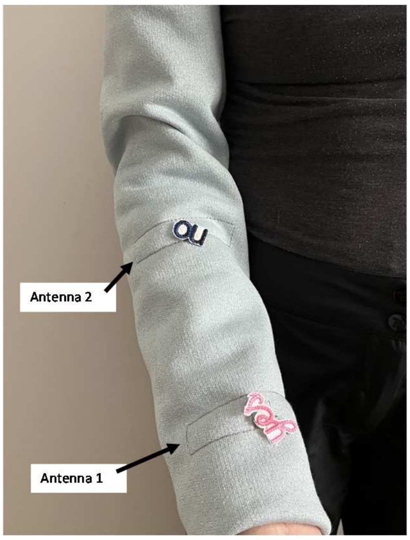


Fig. 5. The ready-made command sleeve with two antennas and two output markers with microcircuits underneath

TABLE II. THE ATTAINED READ RANGES FOR IC AND ANTENNA COMBINATIONS

	Attained read ranges with output markers when both antennas were active (i.e. microcircuits were attached to both antennas)			
	Antenna 1 (near wrist)		***Antenna 2 (near elbow)***	
Test Round	***Marker***	***Read Range (cm)***	***Marker***	***Read Range (cm)***
1	Yes	163	No	157
2	Yes	131	Music	126
3	Yes	150	Location	158
4	No	152	Yes	115
5	No	180	Music	105
6	No	165	Location	99
7	Music	164	Yes	106
8	Music	152	No	153
9	Music	180	Location	147
10	Location	170	Yes	125
11	Location	178	No	125
12	Location	122	Music	156

Interestingly the antenna 1 (nearby wrist) provided better read ranges than the antenna 2 (nearby elbow). Antenna 1 had an approximate read range of 159 cm and Antenna 2 had an approximate read range of 131, even though Antenna 1 was more bent than the Antenna 2 during the measurement. It is important to note that the interconnection made with magnets is not as stable as when sewn or glued on, therefore, it is possible, the bending somehow improved the connection. Then again, Antenna 2 was located near the lossy body, which might have an impact on the read ranges.

IV. CONCLUSIONS

This paper introduced the first version of a command sleeve, designed to support communication and daily tasks for individuals facing challenges in fine motor and communication skills, which can affect their daily activities in various ways. This command sleeve offers a modular RFID solution that allows users to control commands, information flow, and replace broken ICs. The wireless evaluation of changeable IC–antenna combination resulted in approximately 150 cm read ranges, which provides a promising foundation for further research. Future tests will explore different antenna geometries operating near the human body, as well as investigate magnet behavior and its potential impacts on radiation patterns and antenna characteristics.

This initial prototype has some limitations. The pre-defined tasks, here used for proof-of-concept purposes, were ideated by healthcare workers rather than end users, and the construction method, although designed to simplify IC placement and replacement, is relatively complex. The achieved read ranges were modest, indicating the need for further studies to improve wireless performance. Nevertheless, the embroidery technique used in this sleeve allows users (and their caregivers) to customize the appearance of their assistive technology. By choosing colors, threads, symbols, and activation locations, users can create a personalized and visually appealing device. While this command sleeve was designed with individuals with co-morbidities in mind, its concept and logic can be adapted to a wide range of fields, including education, rehabilitation, and home automation, among others. The future work includes testing the sleeve with real users, and subsequent iterations will be improved based on user feedback.

ACKNOWLEDGMENT

We want to express our appreciation to people who ideated and shared their views regarding assistive technology and to Tekstiilipalvelu Ltd, that donated the fabrics.

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