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A User-Centred Approach Exploring the Potential of a Novel EMG Switch for Control of Assistive Technology

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Abstract. This study examines the potential application of an EMG technology as an assistive control method for individuals with severe physical disabilities. The usability and acceptability of a prototype EMG switch was evaluated with health care professionals, researchers and end users using participatory approaches.

Keywords. EMG switch, usability testing, User-centred design, assistive technology

Introduction

Electronic assistive technology (eAT) allows individuals with severe disabilities to control equipment that they would otherwise not be able to access. Switch access is a common method of controlling electronic assistive technology for those that are unable to use other controls such as touch screens, mice or keyboards [1]. Electromyography (EMG) is a well-established technology for detecting the small electrical impulses from muscle activity. EMG has previously been identified as having a potential application as a control method for assistive devices [2]. However, to date, EMG has not been used in any significant way for this application. Recent advances in EMG technology – in the development of 'dry sensors' offer potential to overcome previously identified barriers [1] to the use of EMG.

An EMG switch based on dry sensor technology has been developed and built by GSPK Design – an established electronics design and manufacturing company based in the UK (www.gspkdesign.ltd.uk). The EMG switch comprises two elements: a sensor unit which records the EMG signals and sends these wirelessly to the second element, the base unit which receives the signal and outputs this to the assistive device.

The aim of the study was twofold: 1) to gather performance data on the use of EMG switch and 2) to evaluate the usability and acceptability of the EMG switch with target users. Both aspects of the study aimed to provide information to inform the development of the EMG switch and to ensure it met the needs of the end users.

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1. Methods

An interdisciplinary mixed methods approach was used to engage with different stakeholders in order to develop, test and evaluate the usability and acceptability of the EMG switch prototype with end users. This involved qualitative methods including focus groups, semi-structured interviews, cognitive walkthrough and cooperative evaluation [3] and quantitative methods. Quantitative data were collected on the performance of the EMG switch with end users.

Consultation with clinicians: A discussion group was conducted with the clinicians specialised in using switches as part of a public engagement. The EMG switch was demonstrated to the participants and their views on the advantages and disadvantages of EMG compared with the current available switches were sought. Participants also envisioned ideal switch solutions using envisioning cards and drawing.

Cognitive walkthrough: The prototype was tested with four research colleagues. They were asked to perform a few tasks using the Scanning Wizard tool [4] and to think aloud about how easy/difficult the system was to use, what problems it posed and how these problems could be resolved.

Cooperative evaluation: The EMG switch prototype was evaluated with a convenience sample of seven target users (people with severe physical disabilities) in their homes applying a user-centred design approach, which is used at the early stage of system development. The aim was to test the structure, functionality, usability and acceptability of the system. The outcomes of the evaluation were fed back to the developers, and alterations made to the design for the next iteration of the prototype. Ethical approval for this part of the study was provided by the Sheffield NHS Research Ethics Committee.

Participants were recruited from the caseload of a regional specialist assistive technology service. Participants were included in the study if they: used a switch for an assistive technology application or did not currently use a switch for an assistive technology application but would be able to use a switch if an appropriate means could be found to detect their voluntary movement/muscle activation; were able to give informed consent and to actively take part in the interviews and were over 16 years old.

Participants were not included if they had a cognitive impairment that would have limited their ability to give informed consent or to actively take part in the interviews.

Each participant was visited in their own home. Participants were first asked to complete a simulated assistive technology tasks using their current switch and the Scanning Wizard tool [4]. The EMG switch was then set up to, where possible, replicate the existing switch method. Participants were asked to complete the same tasks, but using the EMG switch. Finally participants were informally interviewed about their experience of using the EMG switch. This process was repeated up to three times, on separate visits, with each participant.

2. Results

From the focus groups the findings of the envisioning activity with eight health professionals suggested that a switch should be: easy to set up, flexible, inexpensive, wireless, easy to position, hypo allergic, infection proof, sensitive, comfortable, easy to maintain, and suitable for a wide range of users. It should be easily mountable or easy

for individuals to hold, with an easy-to-use interface that works with multiple software and systems. The main themes that emerged from the group discussion were:

- Anticipation: Participants described the assessment information gathered prior to assessing a patient to try different methods of access. Participants described that, based on this information, for example, what part of the brain is injured and what muscles have activities and can be controlled reliably, they tended to anticipate the type of access and the location of the device and its acceptability for the user.
- Individual approaches: A variety of methods and ideas were described as being used to find the reliable movements and the correct location for a particular switch or method of access. Participants described that finding a reliable position for a switch can be very difficult ,as can establishing how and where to support and mount it.
- Trade offs - location and acceptability of the switch, accuracy vs speed: Participants described considering trade offs when considering switch access. For example, accuracy and frequency of errors were described as very important. If there is a trade off between speed and accuracy it was felt that in most cases the patients and families prefer accuracy. In order to select a method, clinicians reported needing to compare different methods such as eye gaze, scanning and switches, and then to analyse the amount of physical and cognitive effort needed to use them and the frequency of errors made using these methods.
- Switch interfaces and review: It was felt that the interfaces used for each access method should be designed differently. Further, after selecting a method of access it should be reviewed and revisited based on the changes that occur in the patient's condition over time. For example, with people with MND, if they use eye gaze and the eye muscles deteriorate over time then they should be reassessed to examine the use of alternative methods of access, including switches.
- Involving families in decision making: Participants felt that families should be closely involved in the process of selecting the switch access method and its location. This may vary with the type of disability - for example, soon after acquiring a condition such as a spinal cord injury it may be hard for patients and their families to think clearly and consider using assistive devices. They need to come to terms with the consequences of the condition and the level of disabilities. However, a family of a child with cerebral palsy, may be more ready to consider different methods of access and have different expectations.

The aim of the Cognitive walkthrough with researchers was to examine what the user wants to achieve, whether the required tasks are clear and they are able to perform them, and whether the user can determine if they have made the right choice. Four users took part in the evaluation and they found the Scan test more challenging than the switch test particularly using the EMG switch to perform the task. The individual differences in terms of the structure of the arm and hands had an impact on the EMG signals. For example, in participants with stronger muscles the EMG signals were detected more easily and were more defined. Overall, the participants found the EMG switch and the method of evaluation acceptable with potential to be used with people with communication problems.

In the co-operative evaluation the study participants consisted of four men and three women aged 19-69 with a range of health conditions including Brainstem stroke, MND, a Metabolic condition, Progressive supranuclear palsy, Cerebral palsy, Spina bifida and MS. They use a variety of switches such as a Pal Pad, Spec Switch and Buddy Button.

Prior to the home visit the participants had received the participant information sheet and consent form by email. During the first home visit, the researchers explained the study to the participant and made sure that they are informed about what was involved in their participation. After the informed consent was obtained, the research activity was set up which involved the use of a laptop and the participant's current switch. The current switch was connected to the laptop while Scanning Wizard software was running. Scanning Wizard was used as a measure or instrument to assess the performance of the participant using their current switch and later the EMG switch. The participants were asked to carry out two tests and the results of their performance were saved. Next, the EMG prototype was set up and the sensor was attached to the participant's hand by a Velcro strap. Different hand and wrist muscles located on hand and forearm were tested with the EMG sensor to identify a muscle that its signals can be picked up by the sensor.

For example, participant P2 is a 66 year old man with MND. He uses a Buddy Button switch, using his thumb to press the switch by performing the adduction movement. He was able to use the EMG switch to perform the tasks involved in the Scanning Wizard with good accuracy. He felt that the EMG switch has potential, however, he felt that the prototype needed to be improved to address a few usability problems, predominately to be smaller and be more stable when it is attached to the body. As another example, participant P4, a 69 year old woman, has used different access methods in the past including Eye Gaze, switch on wrist, and wheel on chin but none of them had worked to her satisfaction. She has progressive supranuclear palsy. Different arm muscles and facial muscles were tested with the EMG switch but no usable EMG signals were detected and so the switch was not able to be set up with her.

Interview data and researcher notes from the cooperative evaluation sessions with users were analysed. These data from the usability testing with the participants are categorised into two main themes relating to the advantages and disadvantages of the switch.

The summary of the advantages participants felt the EMG switch had:

1) Less tiring.
2) Had a quicker reaction.
3) Was wireless and moves with the user.
4) More suitable when the user is tired.
5) When the user has no or very limited muscle activities the EMG could pick up muscle signals and could stand a better chance of working than other switch methods.

On considering disadvantages, participants felt:

1) Accuracy could be less than the current switch - in some cases the switch was triggering when the user did not intend to trigger it.
2) There is no physical feedback with the use of the switch.
3) The location of the EMG sensor is not stable.
4) The prototype used was too bulky and heavy and needs to be refined to be smaller.

5) The prototype fixing used could be prone to move in use.

3. Discussion

EMG switches may be predominately suitable for those with minimal movement as currently fewer options are available for this group of patients. Key features established are that the switch should be wireless and simple to use. The main challenge to use of EMG is in identifying the patient's muscle function, locating the muscle(s) involved in the function and reliably setting up the EMG switch to capture this muscle activity.
The findings of each aspect of this study have been reported to the EMG switch developers and were considered in the design of the pre-production version of the device (http://emego.co.uk/).We will continue evaluating the prototype formatively with end users using user-centred design methods. Further research is needed to examine the acceptability and clinical effectiveness of the EMG switch as an intervention.

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