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704. The Design of a Wearable Robotic Upper Limb Stroke Therapy Device that Addresses Acceptance and Initiation of Use.

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ABSTRACT *This study investigates patients' acceptance of a robotic device for stroke rehabilitation and how its design elicits initiation of use of the affected upper-limb. Stroke is one of the leading causes of long-term disability globally. Stroke affects the brain and motor function. Patients often don't receive the recommended amount of therapy, which robotics have the potential to deliver through real tasks and digital games. Patients and clinicians can have negative perceptions of these new technologies, which may be preventing initiation of use and acceptance of these new devices. This study addresses some of the barriers to the design of new medical technology devices for stroke therapy and the implications that may have on delivering healthcare.*

Clinicians and patients were interviewed through stroke clubs. Using an existing robotic acceptance framework, criteria were constructed to produce initial concepts through an iterative design process. Prototypes were assessed with clinicians and patients to then create a final design.

This paper presents the main findings from designing and testing the prototype with stroke patients; including ease of use, how acceptance and initiation of use were implemented. We discuss a framework for robotic acceptance to designing future wearable robotics for stroke rehabilitation.

Keywords: design, stroke, Stroke therapy, Upper limb rehabilitation, acceptance, stigma, initial use, change.

Introduction

Stroke is a leading cause of disability, and occurs predominantly in older adults (Feigin et al. 2014; National Heart Lung and Blood institute 2016).

Stroke leaves patients with long term impacts including reduced motor function. The majority will have impaired upper limb function (Weiss 2010). This impedes patients' ability to carry out daily tasks and requires therapy by clinicians, devices and aids for recovery (Stroke Foundation of New Zealand and New Zealand Guidelines Group 2010; Kwakkel, Kollen, and Wagenaar 1999).

Patients are not receiving the recommended amount of therapy for recovery. 23-32 repetitions of a singular exercise per day instead of 400-600 (Kimberley, Samargia, Moore, Shakya, & Lang, 2010) (Lang, MacDonald, and Gnip, 2007), and are receiving 2hours 45 minutes less than recommended (Australian Stroke Foundation, 2017; Stroke Foundation of New Zealand, 2010).

Robots are increasingly being proposed to fill therapy gaps; they can measure, assess, support recovery, and maintain independence of older adults (Wu et al. 2014; Blackman 2013). Perceptions of robotics can be negative, affecting acceptance (Wu et al. 2014). In general, this is not addressed in current robotics, however, design in medical devices can improve comfort, aid therapy and increase acceptance and uptake by focusing on design (Vaes, 2014; Smarr et al. 2012; Wu et al. 2014). The design is important to the user perception, leading to higher acceptance of the devices (Wu et al. 2014), and increased uptake. The outcome being increased therapy received, leading to motor function recovery.

This study investigates the design of wearable stroke rehabilitation robotics to increase acceptance and initiation of use (Lemke, Rodríguez Ramírez, Robinson 2017) of a pre-existing system. The robotic system manipulates hand grip using electronics (Figure 1), to pull a system of artificial tendons (strings) (Rajendran, Hollitt, and Browne 2011). It can deliver passive motion, and assistive motion which finishes patient movement (Rajendran, Hollitt, and Browne 2011). The device (Figure 1) delivers repetitions for therapy and everyday activities, and data can be recorded. There has been some consideration to the cost, size and weight, but not into how the device is perceived by patients and clinicians.

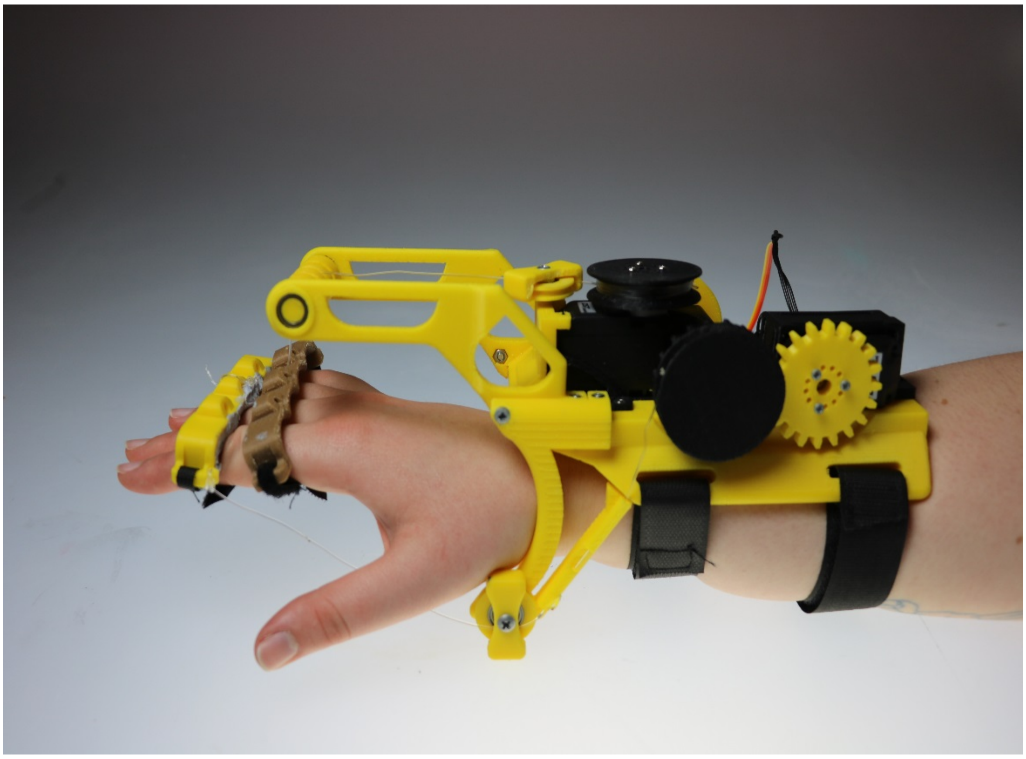

Figure 1: pre-existing robotic prototype to be redesigned in this project to increase acceptance in users. Upper strings (set 1) use a motor to pull up and open the hand. The lower arms pull the fingers forward and into a grip using string (set 2).

Methods

Research through design (Krogh, Markussen, and Bang 2015) was chosen for the overarching design process methods including iterative design (Rodríguez Ramírez 2017, 14).

Semi-structured interviews and Expert Reviews with Clinicians (Kuniavsky 2003, 447) were used to gather qualitative and quantitative data. To gain insight into therapy practices and how clinicians use robotic devices Thematic analysis was used to interoperate data (Alhojailan 2012, 40–45) and create design criteria.

A Robotic Acceptance survey as used as a framework then adapted into interviews (Wu et al. 2014, 804) to test our robotic device designs.

Results

Design process

Acceptance was explored through iterative design methods focusing on our constructed criteria. Features of everyday universal products to wear on their upper limb were analysed (Vaes 2014). Our final prototype encompasses aspects of gloves (Figure 4), medical braces and sports protection (Figures 5-9). Other product features including jewellery were also considered.

The prototypes developing aesthetics and function were explored through drawings, and prototyping with 3d printing of components on and with fabrics. The focus was on designing for features that were important to the users' acceptance which included ease of use, promoting acceptance and initiation of use. Velcro was found to be the easiest technique to understand and use for both patients and clinicians in the don (putting on) and doff (taking off) process. This combined with a simple slide on under sleeve with attachment locations and straps that position and support the robotic components (Figure 5, 6 and 9). There was also consideration for comfort, cleanability, profile and weight.

The undersleeve is tailored for fit, padded and lightweight sections for comfort, and the positioning and support of the robotic components, and is removable for cleaning (Figure 5 and 9). The robotic components have been reduced in profile, re-designed to prevent strings blocking the grip (Figure2a, 2b,3 and 9), reducing the cumbersome arms (figure 1), and providing cohesive form, aesthetics and attachments.

The final device aesthetics, function and usability are designed for both use at hospital and at home for therapy and daily tasks (Figure 9).

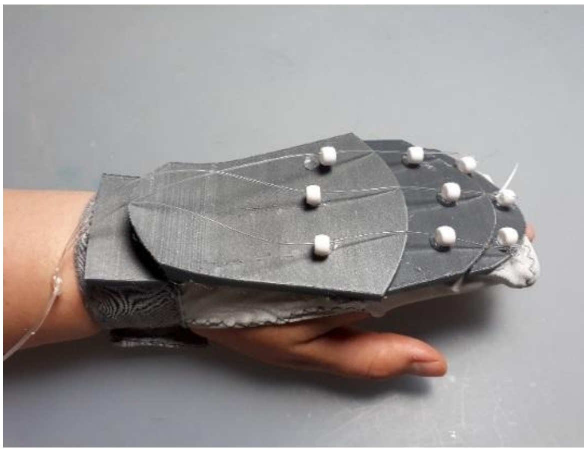

Figure 2a: armadillo plates prevent hyperflexion

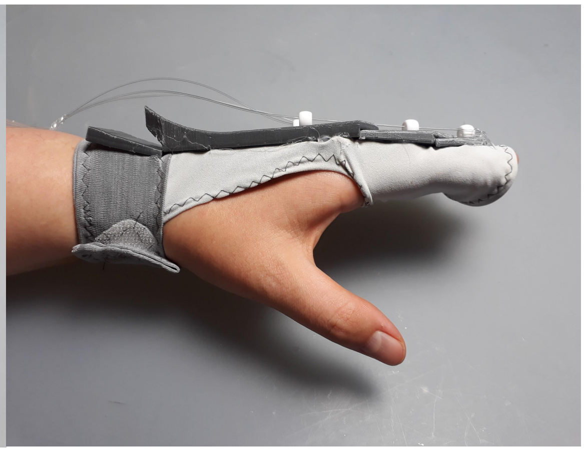

Figure 2b: string pulls, the hand opens

Figure 3: string set 2 helps close hand

Figure 4: glove with palm/fingertips free to grip

Figure 5: Tailored sleeve, removable components , stitched markings for reassembly and black padded attachment points .

Figure 6: pulling on the sleeve with components attached

Figure 7:'wrap' Velcro don/doff reduces strap complexity

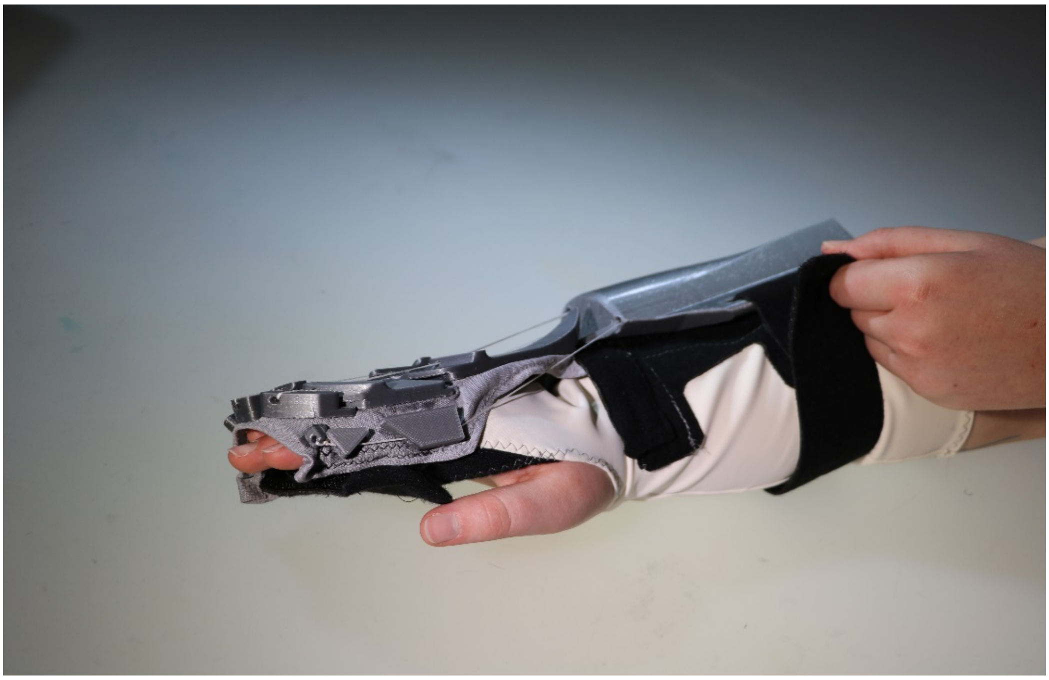

Figure 8: adjusting the robotic support strap

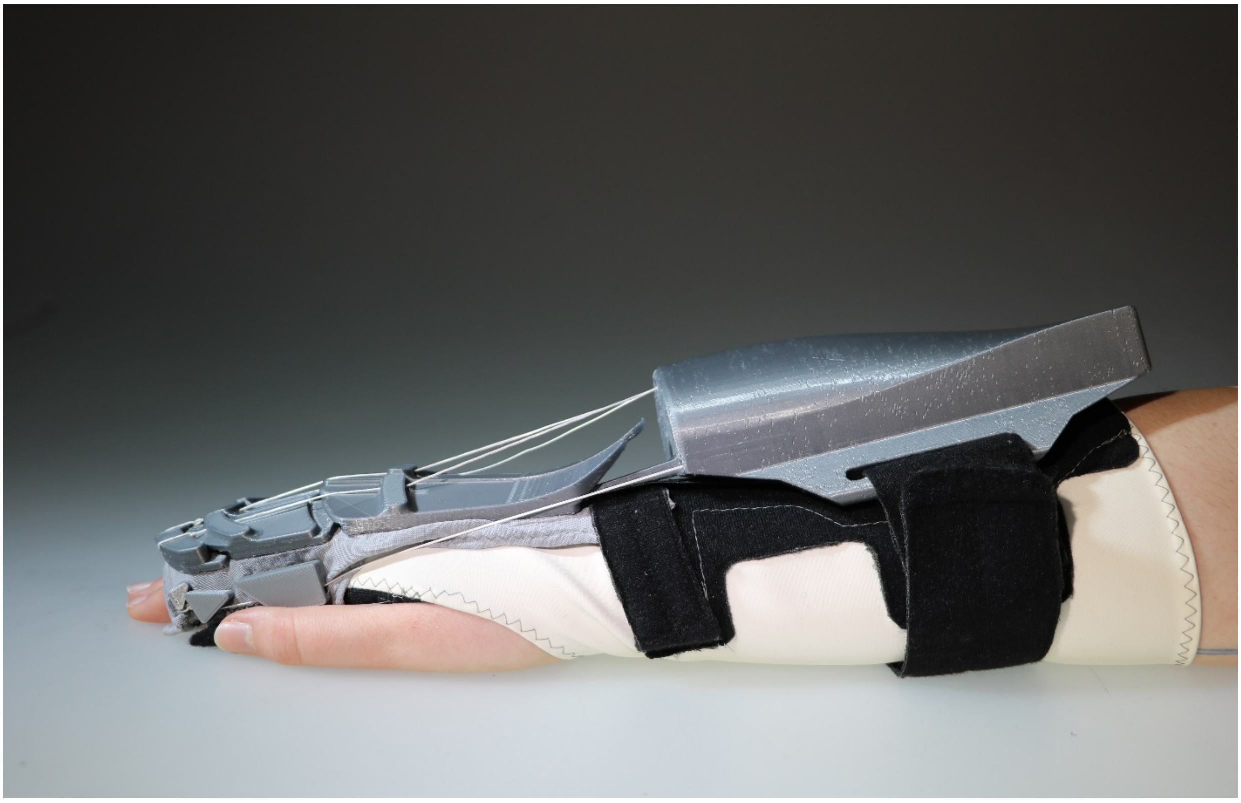

Figure 9: new design of device

Testing

Testing was carried out through a series of interviews and testing sessions, that were thematically analysed for design criteria. Participants were accessed through stroke clubs and conferences. Inclusion criteria for patients were mild weakness of the upper limb on one side of the body, one stroke event and high communication ability, and for clinicians, involvement in upper limb stroke therapy. Participants read information sheets and signed consent forms. Participants involved were three patients and three clinicians.

Interviews were carried out in patients' homes, clinicians' offices or digitally. Prototypes were introduced in order, and participants could choose to touch and try on prototypes. Interviews were recorded with audio, photo and or video recording.

The key factor from the framework is that perception of robotics is an indicator of robotic acceptance (Wu et al. 2014). Patients were positive about robotics in general prior to being introduced to proytotypes, and had neutral or positive feedback on the designs. Other factors include use of aesthetics of items generally worn on the hands , drawing from universal design (Vaes 2014).

This study found design criteria for acceptance are: ease of use, comfort, lightweight/portable, independent use, unit profile, cost (see pre-existing), cleanable. These criteria were implemented back into the design process (see design process).

Other found factors included: aesthetics unimportant and that the device delivers the promised function, and recording measurements.

Discussion

The design of robotics needs to consider the impacts on subjective and social factors as well as delivering the task (Kiesler and Hinds 2004, 4–5). Although The aesthetic features that seemed important in the literature (Vaes 2014); they were not as important to the interviewed individual's acceptance and initiation of use of the prototypes as indicated by the literature. How the device is applied was the factor important to all participants, among other found criteria. There were also different considerations needed for clinicians including the addition of measurement for patient outcomes.

The limitations of this study are: the focus on the structure holding the robotics and attachment rather than programming the robotic components itself. Prototypes tested with patients were about the initial reaction and don and doff, not testing the functioning of the robotics. Patient participants were all male, and accessed through stroke clubs when an outpatient. All participants chose to be involved in a robotic study which may indicate a possible elevated robotic acceptance rate, and potential reduced importance on the aesthetics.

Future studies should explore a larger patient population and test individuals with both low and high perception of robotics.

Conclusion

Stroke is a major cause of motor impairment, and acceptance and initiation of use are significant in the uptake therapy devices. The study found that users valued ease of use, comfort, lightweight, low cost and the ability to wash the product. The product aesthetics were not highly valued but were improved as an outcome of design process. The device exterior was developed into a final model that was reduced in profile and the attaching strings streamlined and attached to familiar sleeve base to provide a more functional and easy to use device for the patients, and incorporation of measurement data providing potential improved clinician acceptance, increasing device use in practice. Product design could address barriers and enable increased therapy delivery, accessibility and use of devices.

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