A blended design approach for pervasive healthcare: bringing together users, experts and technology

van der Linden, Janet; Rogers, Yvonne; Waights, Verina and Taylor, Crissman (2012). A blended design approach for pervasive healthcare: bringing together users, experts and technology. Health Informatics Journal, 18(3) pp. 212–218.

A Blended Design Approach for Pervasive Healthcare: bringing together users, experts and technology

Janet van der Linden, (PhD)

Department of Computing

The Open University

Milton Keynes, MK7 6AA, UK

j.vanderlindenopen.ac.uk

Yvonne Rogers, (PhD)

UCLIC

University College London

Malet Place Engineering Building

London, WC1E 6BT, UK

y.rogers@ucl.ac.uk

Verina Waights (PhD)

Faculty of Health and Social Care

The Open University

Milton Keynes, MK7 6AA, UK

V.waights@open.ac.uk

Crissman Taylor (MM, STAT)

Utrecht Conservatory

Utrecht School for the Arts

Utrecht, Holland

criss.taylor@muziek.hku.nl

Abstract —

Pervasive healthcare is beginning to investigate how novel sensory technologies can be used to measure body movements and provide various forms of feedback. This position paper reflects on a blended design approach that uses a combination of technology-inspiration, consultation with experts and user-centred design for the development of a personalized pervasive health care system to support stroke rehabilitation.

Keywords

hardware prototyping; pervasive healthcare, rehabilitative physiotherapy, sensors, stroke, technology inspired design, vibrotactile feedback

I. Introduction

Pervasive healthcare is about understanding healthcare problems from a technological, social and medical perspective and about developing and evaluating technologies that help integrate healthcare more seamlessly into everyday life, regardless of space and time. It is about systems that help individuals with day-to-day rehabilitation exercises, help professionals make accurate assessments in a variety of settings and for lightweight monitoring methods of progress that can be accessed from anywhere [1-5]. Designing such systems is a complex process, requiring an interdisciplinary approach and team efforts.

In this position paper we elaborate on some of the thinking underpinning the design of a pervasive health care system to support people recovering from stroke. We address the following questions: What was our main inspiration? What experiences did we bring to the project? At which point did we bring in the end users? How did we collaborate with health professionals?

Why stroke?

Worldwide, stroke is the largest cause of adult disability. Each year, in the UK alone, an estimated 150,000 people have a stroke and at least 450,000 people are severely disabled as a result of having a stroke [6, 7]. Following stroke, people find themselves hospitalized or receiving hospital services at home, with subsequent need for further rehabilitation and lifestyle adjustments. Rehabilitation exercises carried out regularly can significantly improve a person's recovery, not only in the early days following stroke, but also long after they have returned home [8]. However, it is difficult for people to exercise by themselves, without the presence of the physiotherapist, because most people have difficulty remembering exactly *how* to do their exercises but also require hands-on physical guidance to help them exercise correctly. Hence, there is a large population of people who could benefit from technological support that both reminds them of how to do their exercising but also that would emulate the role of the physiotherapist, by giving personalized and tactile support.

Potential of Novel Technologies

Recently a range of ubiquitous computing technologies have been developed for healthcare. In particular, there are now novel sensors and mobile devices that can be used to measure and monitor a variety of human activities in the home - for example, for the detection of the number of steps taken, the detection of sitting and standing postures, or the precise angle between the upper and lower arm of a person stretching their arm [3,4,9]. There is much potential for using these versatile and lightweight technologies in the development of augmented rehabilitation therapy for people with stroke [10].

However, there are many challenges involved in the design of computer-based rehabilitation systems: How do people understand and adapt to new ways of exercising with ‘augmented sensory technologies’; and how do we take into account both the cognitive and physical abilities of the intended users of the system? [5].

In this paper, we emphasize why it is important to use a blended approach for the design of a pervasive healthcare system using a combination of what we refer to as technology inspiration but also user-centred design and consultation with professionals. We discuss our blended approach in the design for a system to augment physical rehabilitation therapy for people recovering from stroke at home. It builds on our previous work for giving physical, tactile guidance on movement and posture during the training of motor skills in a non-healthcare domain – that of learning to play the violin.

II. USER CENTRED APPROACHES

A User-centred approach takes the specific needs of a group of users into account, from the onset of designing a system, and works with them throughout its development. The rationale for involving users is to try to ensure that the system under development is usable, comfortable, understandable and acceptable to the users. User involvement in healthcare projects is now a requirement for most funded projects, but projects differ in when they involve users – for some this is early on when the ideas are being formed and in others it is during the later stage of the evaluation of the system [11]. However, many users feel products in general come to market without sufficient involvement of users in the design and many could be significantly improved with user input.

We advocate involving users early on in the project cycle and illustrate this with two examples. DIMA is a system designed to enable people with chronic renal disease to carefully monitor their fluid intake [12]. Such people are restricted in the amount of fluid they consume, and have to make complex calculations throughout the day to avoid exceeding their prescribed daily amount. A handheld PDA system, that also included a barcode scanner, was developed to support these individuals. By pointing their PDA at products they were about to consume, participants were able to keep a very strict count of how much they had consumed that day. Early on in the development the researchers provided them with paper-based prototypes to ascertain whether they would be able to use the new PDA system. This revealed that a large proportion of the targeted end user group had reading problems, leading to the design of non-text based interfaces that used speech input, bar scanning input, and visualisations and images of food as output.

The value of involving users at an early stage was also demonstrated in the SMART project, with their sensor-based system for arm stretching to support people recovering from stroke [9]. Through hands-on workshops with groups of clients they explored how best to attach the sensor to the upper arm. They investigated which type of armband, and which type of fastener, would be easiest to put on, given that these individuals usually have very limited movement in their upper limbs. Interestingly, a fastener that seemed simple to the researchers caused too much friction for people to put on, while a solution that seemed overly complex to the researchers, was preferred by people after they had tried it a few times.

These two examples illustrate how involving users early on in the design process lead the system design in particular directions, averting potential problems which would have affected the usability and acceptance of the final product. In the first case, a simple paper prototype was sufficient to elicit user responses, in the second case, physical prototypes were used as it was the users' ability to put on and take off the armbands that was under investigation.

III. TECHNOLOGICAL INSPIRATION

Physical prototypes are also used in novel ubiquitous computing approaches, referred to as *sketching in hardware*, or *physical computing* [13]. This involves building physical, partially working prototypes, usually with a variety of sensors that interact with the physical environment. Such prototypes provide full interactive functionality, but usually do not have the aesthetically pleasing look and feel of a final product. They are put together from electronic toolkits such as Arduino and various electronic components, using a variety of DIY techniques such as hardware hacking, modding, and mashups [13,14,15]. This process of rapid prototyping can go through a number of cycles, where user reactions feed into the next iteration of the prototype.

Apart from helping the users understand the design, prototyping is important for the designers, because building the physical system is a helpful way of learning about the affordances of a system, which can be difficult to do during the thinking phase [16]. Rogers et al. [17] use the term 'technology inspired' to describe the process where the capabilities of new technologies are explored and experimented with, in order to provide ideas for new conceptual development and interaction design. They explored how RFID tags, barcodes, GPS devices, ultrasonics, accelerometers, pressure pads and aerials could be used and combined to create a mixed reality environment for children to learn in. The approach emphasizes examining the affordances of a technology for design inspiration, investigating where and how it may be used in innovative ways.

IV. Motor Skills training

For the design of the stroke rehabilitation system, we drew on our previous experience of developing MusicJacket - an innovative pervasive system for music learning [18]. Both the technology and the methods used are highly relevant approaches for developing novel pervasive healthcare systems, using unknown technologies and user-centred methods.

The MusicJacket system was developed to help people learn to play the violin by using *haptic feedback*. That is, it uses the sense of touch embedded in a jacket to give the wearer a sensation that someone is gently ‘nudging’ their arm into the correct position. Real-time feedback is delivered through vibration motors, similar to those found in most mobile phones. These motors were programmed so that when the player’s bowing moves too far from the target trajectory that is set for them, the player feels a gentle buzz, whereas feeling no buzz means that they are on the correct path.

During the development of the MusicJacket we worked with a number of professionals, including violin teachers, physiotherapists and an Alexander Technique trainer and various groups of users, including children who experienced the MusicJacket as an integrated part of their lessons during a two month period. They helped us find out whether people would be able to react to haptic feedback while they were involved in making music. They also helped decide where precisely to place the motors so that the feedback would be easy to interpret and would feel as if a teacher ‘touched’ their elbow to gently ‘nudge’ it to the right position while they play.

While exploring and experimenting with the setting of the vibration motors, the health professionals explained how this technology gave them an increased awareness of where parts of the body were in relationship to each other. In particular, they mentioned how vibration on the torso combined with vibration on their elbow, gave them an awareness of a spatial triangle, that was changing shape as they moved their arms and body. We speculated how this spatial triangle could be used in training or treatment, giving people a novel type of metaphor to focus on and a greater awareness of their own body while learning how to move their body in a different way. This increased a proprioceptive sense, which lies at the core of most physiotherapy treatments, and came about as a direct result of exploring the potential of the technology.

V. Discussion

These insights inspired us to develop a gesture-based system to facilitate the rehabilitation of people with stroke. There is growing evidence that rehabilitation exercise done regularly and well, can reduce disability and increase independence. However, rehabilitation exercises can be demotivating as they involve challenging, demanding, time-consuming and often uninteresting repetitions of basic movements that must be practiced correctly. In stroke rehabilitation, physiotherapists often stroke or tap the part of the body that they want the person to use; for example, the torso to encourage them to sit up straight, or the arm, in order to encourage reaching for objects. This touching helps the person focus and gain awareness of the impaired part of their body. This immediate feedback disappears when the person is by themselves at home, often leading to them stopping their exercises.

The purpose of our system is to motivate and guide people through a schedule of tailor-made physical exercises that will give real-time multi-modal feedback. Although haptic systems have been used previously to help clinicians/people with stroke to monitor progress in their rehabilitation [19], none to date provide instant feedback that mimics a physiotherapist's touch. Our system includes:

- Simple visualisations that people can follow on their computer/TV screen, consisting of patterns of dots to reach for, or lines to follow. The patterns will change pace and complexity as the person's exercising improves.
- A haptic feedback mechanism, using vibration motors, which will emulate the sense of human touch that people experience during a physiotherapy session to encourage them to move their impaired limb or trunk during the exercises. An adapted version of the Music Jacket is easy to put on for someone who is frail and has restricted limb movements.

Expert consultation

To enable us to appropriate this form of technology design effectively in the context of rehabilitation exercising we consulted with health professionals and stroke support groups. During these consultations we used modified parts of the MusicJacket in order for health professionals, people with stroke, their relatives and carers to experience how the haptic feedback would work in practice. We found that people with stroke reported different sensitivities for the vibrotactile feedback, some not feeling it at all, others feeling it resonate through their bones, rather than through their skin, while others were surprised how clearly they could feel the feedback. The physical feedback components therefore need to be easily adjustable by physiotherapists to meet individual needs. This also highlights the importance of consulting a sufficiently representative group of users as people with stroke have a wide range of abilities.

We also provided an off-the-shelf entertainment system - the X-Box Kinect (which is gesture-based and does not require players to hold a remote), to enable people with stroke and their carers to try playing together, using simple games based on movement of the upper body. Previous studies have shown gaming systems can motivate older people to exercise and improve their balance [3,20]. However, our consultation showed that although entertainment technologies brought pleasure due to the social context, they can pose problems for people with limited mobility. In particular, we found that this group of people has a much slower reaction time, which creates problems with the standard pace of the game. Furthermore, the initial calibration for the system, requiring the person to stand with their hands above their head, posed significant problems as many people with stroke were not able to do this.

The consultation with health professionals, including hospital and community-based physiotherapists and consultant neurologists, highlighted the importance of following the person on their recovery journey. People should be introduced to the system in hospital, and continue to use it at home in-between visits from community physiotherapists as following stroke, early physiotherapy that is continued in the weeks following discharge is known to improve recovery and increase independence [8]. There is often a long period between discharge from the early stroke rehabilitation team (six week post hospital discharge) and access to the neuro-rehabilitation team when people can feel isolated and unsupported [7]. Physiotherapists are time and finance poor and welcome an inexpensive approach that will help 'bridge this gap' and augment their home visits to aid recovery.

Future work

The next step of our project is to follow an iterative design approach, involving people with stroke; healthy representatives of similar ages; physiotherapists and interaction designers. In particular, we will work closely with physiotherapists specialized in treating neurophysiological conditions to develop individualized exercise regimes for people with stroke and to set target movements. This will also involve consulting people with stroke who have just come out of hospital and are starting their exercises at home.

We plan to conduct two main phases of user studies. First, we will work with healthy adults as participants, to determine how effective haptic feedback is for increasing motivation and accuracy of movement in the exercises. Our hypothesis is that the haptic feedback will increase motivation and in turn, improve well-being. We will develop measures of effectiveness using standard physiotherapist's assessment procedures but also investigate the levels of enjoyment derived from using the system and how this motivates regular exercising.

In addition, research has shown that although family members are willing to participate in informal exercises to assist recovery from stroke, family involvement in physiotherapy is not practiced routinely following stroke [21]. Some of these exercises will be designed to also have a social component so that the person recovering from stroke can play with others if they wish.

The second phase will be conducted as an in-the-wild user study, involving people recovering from stroke, using the system in their own home over a period of six months – to measure the long-term effects of such a system that is geared towards primarily improving motivation when people exercise alone.

VI. CONCLUSIONS

We have described a blended approach for exploring how new technologies can inspire the design of new pervasive applications that use real-time feedback to correct certain physical behaviours. This was illustrated by a new system to enhance rehabilitation physiotherapy following stroke. An important aspect of our approach is to engage with end-users early on in the design process to ensure it meets their needs and with experts in the field, who can make sense of these ubiquitous technologies. This approach also responds to user concerns about the lack of consultation during development of new products. Our approach also advocates ensuring that new pervasive healthcare systems need to show how they can fit in with someone's lifestyle by being comfortable and easy to use and their benefits must be clear to the wearer. To assess these aspects requires evaluating them in the wild.

VII. References

[1] Kowalczewski J, Prochazka A. Technology improves upper extremity rehabilitation. *Prog Brain Res.* 2011;192: 147-59.

[2] Aarhus, R, Grönvall E, Larsen SB and Wollsen,S. Turning training into play: embodied gaming, seniors, physical training and motivation. *Gerontechnology* 2011 10 (2):110-120

[3] Niazmand K, Tonn K, Kalaras A, Lueth T, Kammermeier S, Boetzel K and Mehrkens, J. A Measurement Device for Motion Analysis of Patients with Parkinson' s Disease using Smart Clothes. Proc. Pervasive Healthcare 2011.

[4] Frenken T, Vester B, Melina Brell, M and Hein, A. aTUG: Fully-automated Timed Up and Go Assessment Using Ambient Sensor Technologies, *Proc. Pervasive Healthcare* 2011.

[5] Arnrich B, Mayora O, Bardram J, Troster G. Pervasive healthcare: paving the way for a pervasive, user-centered and preventive healthcare model. *Methods Inf Med.* 2010;49(1):67-73.

[6] Office of National Statistics Health Statistics Quarterly. Stroke incidence and risk factors in a population based cohort study.,(12) Winter 2001

[7] National Audit Office Report. Department of Health, Reducing Brain Damage: Faster access to better stroke care, 2005.

[8] Galvin R, Cusack T and Stokes E. To what extent are family members and friends involved in physiotherapy and the delivery of exercises for people with stroke? *Disability and Rehabilitation* 2009 31(11): 898-905

[9] Mountain G, Ware P, Hammerton J, Mawson S, Zheng H, Davies R, et al. The SMART Project: A user led approach to developing and testing technological applications for domiciliary stroke rehabilitation. *Designing Accessible Technology*, 2006, (III), 135-144.

[10] Zheng H, Black ND, and Harris, ND. Position-sensing technologies for movement analysis in stroke rehabilitation. *Medical and Biological Engineering and Computing*, 2005, (43): 4, 413-420

[11] Ghulam Sarwar Shah S, Robinson I. Benefits of and barriers to involving users in medical device technology development and evaluation. *International Journal of Technology Assessment in Health Care.* (2007), 23(1): 131-137.

[12] Siek K, Connelly K, and Rogers Y. Pride and prejudice: learning how chronically ill people think about food. Proceedings CHI '06. ACM, 947-950.

[13] O'Sullivan D and Igoe T. Physical Computing: Sensing and Controlling the Physical World. 2004, Premier Press.

[14] Hartman B, Doorley S and Klemmer S. Hacking, Mashing, Gluing: Understanding Opportunistic Design. *IEEE Pervasive Computing*, (2008) vol. 7, no. 3, 46 – 54.

[15] Bird J, Marshall P and Rogers Y. Low-Fi Skin Vision: A Case Study in Rapid Prototyping a Sensory Substitution System. *Proceedings HCI* 2009, 55-64.

[16] Klemmer S, Hartmann B and Takayama L. How bodies matter: five themes for interaction design. *DIS2006*, 140 – 149.

[17] RogersY et al. Things aren't what they seem to be: innovation through technology inspiration. *DIS2002*, 373-377.

[18] van der Linden J, Schoonderwalt E, Bird J and Johnson R. MusicJacket: Combining Motion Capture and Vibrotactile Feedback to Teach Violin Bowing. *IEEE Transactions on Instrumentation and Measurement,* (2011), 60 (1) .

[19] McGill University (2011, April 26). New sensor glove may help stroke patients recover mobility. ScienceDaily. Retrieved July 20, 2011, from http://www.sciencedaily.com-/releases/2011/04/110426122952.htm

[20] Wiihabilitation. Downloaded on 10/03/2011 from http://www.wiihabilitation.co.uk/

[21] Department of Health. National Stroke Strategy Impact assessment: a new ambition for Stroke (2007) Downloaded on 27/07/2011 from DH.gov.uk