Integrating Tangible User Interfaces into Stroke Survivor's Everyday Activities at Home

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Abstract
A successful stroke rehabilitation process requires typically repetitive exercises to be conducted at home after discharge from hospital. The problem with the exercises is that rehabilitees find them boring and tedious. In order to overcome the problems of discontinuing the training, we have started a three-year project, called ActivABLES, on how to integrate tangible user interfaces (TUIs) into everyday activities of stroke rehabilitees at homes. Coupling TUIs with the day-to-day activities enables digital computing which provides new possibilities (e.g., better feedback) for supporting continuation of rehabilitation. In this position paper, we present our research approach on stroke rehabilitation and provide research challenges to be tackled in the field.

Author Keywords
Tangible User Interface; stroke; rehabilitation; activity of daily living; home

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Stroke is the most common cause for adult long-term disability in developed countries [4]. Stroke survivors experience a wide range of physical and psycho-social impairments, and approx. 50 % of persons have to rely on human assistance for help in activities of daily living (ADLs) such as getting out of bed, dressing, walking and eating. Repetitive nature of the exercises that support ADLs has been found to reduce interest and commitment. This leads to low confidence and a lack of motivation to continue, leading to patients discontinuing training. According to [6] only 31% of stroke survivors perform the exercises that support ADLs as therapists recommend. Thus there is a need for technological exercise forms that augment rehabilitation exercise in between formal therapy sessions or after discharge from hospital.

Previous Approaches

Different approaches have been developed for encouraging stroke rehabilitees to continue training. Balaam *et al.* [3] concentrated on motivations of rehabilitees and designed stroke rehabilitation systems based on individual needs. They came up with different simple designs depending on the survivor's rehabilitative focus. For example one stroke survivor had impaired hand and liked reading so Balaam et al. [3] designed a TUI that changed a page of a book when squeezing a sensor. This example illustrates that the exercises can be effective and enjoyable at the same time. Exergames provide an approach where rehabilitation is tuned more towards fun, enjoyment and feeling of achievement through benefits of digital processing and gamification. Alankus [1] gained good results in improved motoric skills, evaluated with one stroke survivor, within a six week period. However, the reason for increase in skills remained unclear and no longer time period was investigated. According to the authors' knowledge, the exergames have not been coupled tightly with day-to-day activities and need to be taken into use separately when starting an exercise.

Our Approach

Our research project, called ActivABLES (www.activables.org), conducted in collaboration with the University of Lund and the University of Iceland aims at developing tangible user interfaces (TUIs) for devices to be used in either in ADLs or in other common physical day-to-day activities (such as using a remote control or turning a page of a book).

We aim to develop TUIs that can be integrated into everyday activities in order to get benefits of adding digital computing to them (e.g., movement detection, action logging, feedback and connections to other devices). Our approach is to turn existing objects found from homes (e.g., remote control, pillow, light switch or door knob) into TUIs or to introduce new devices such as dedicated ball. Following this approach, we are interested in how to lower the threshold (e.g., increase motivation by showing progression) of starting physical exercises so that they would become part of rehabilitees' daily routines. In order to stroke survivor to start an exercise she/he just has to start her/his everuday activity using the TUI.

Integrating the TUIs into everyday activities enables a systematic evaluation of progress as they are conducted frequently. Altogether, many of the everyday activities are physical, so coupling TUIs with them is a natural angle to approach the stroke rehabilitation.

Getting training through TUIs as byproduct of everyday activities provides interesting possibilities. For example, TUIs can be used to support stroke rehabilitee to get out from bed in the morning with a correct balance between legs by attaching pressure sensors to the bottom of socks. When the pressure difference between the legs is small enough, a radio is turned on. Another example is that the TUI is coupled with TV, and in order to change TV channel, a stroke survivor must squeeze a cushion with a force that is mapped to a certain TV channel. There is a clear advantage of using mobile, small and easy-access TUIs coupled with existing domestic devices compared with specific rehabilitation devices (such as complex gloves or exergames) that need to taken into use separately when starting an exercise.

Design Aspects of Our Approach

Based on literature and initial interviews with six occupational therapists and physiotherapists at least following issues should be taken into account when designing TUIs for everyday activities of stroke rehabilitees.

Home as a Stroke Rehabilitation Environment

Home is not an optimal rehabilitation environment due to a limited space, suboptimal ergonomic conditions and there are specific locations at the home that are good for conducting exercises [2]. For example, exergames require typically a large display screen (such as a television) and an open space for conducting the exercises at home. However, the exercises should be able to conduct without causing disruption to other persons living in the same household, which is difficult with large and static devices

Input (Manipulation)

Usually stroke impairs either the left or the right side of the body. TUIs can be used to detect which of the hands (i.e. unaffected or affected) is using the device and respond accordingly. For example, a remote control can stop working if used only with an unaffected hand. Moreover, the TUIs should be designed so that the unaffected limb can be used for helping the affected limb.

Feedback

Providing feedback is important in order to instruct the stroke survivor how the activities should and should not be conducted. However, accuracy of perceiving feedback is decreased due to impairments caused by the stroke, and thus the feedback modality (visual, auditory, tactile, kinaesthetic, thermal, olfactory or gustatory) should be carefully chosen. Based on initial interviews with rehabilitation therapists, the use of sounds and different intensity levels of light are good feedback methods. For example, outcomes of the exercises can be visualized by making a ball to glow brightly when it is squeezed enough enabling the ball to operate as an ambient display. The feedback can be either explicit (e.g., showing a number of conducted repetitions) or implicit (e.g., showing a bright green color when a correct number of exercises have been conducted).

Progress Monitoring

Currently, rehabilitation therapists have to rely on survivors' self-reports on how much and how often they conduct exercises. This causes ambiguity in evaluating the effectiveness of rehabilitation as the survivors' self-reports do not necessarily respond to the reality, for example due to decreased level of self-awareness or intentional over-reporting [5]. TUIs enable logging data of the activities that can be reviewed by the rehabilitee her/himself, caregiver or rehabilitation therapist, which allows monitoring the real progress in activities. Naturally, sharing the data with others must be agreed with a rehabilitee.

Rewards
Rehabilitees cannot avoid compulsory ADLs (such as eating and dressing) and conducting day-to-day activities independently can be rewarding itself (such as going outside to have fresh air). However, that is not always enough and more motivation is needed. Rewarding, in addition to positive feedback, is one way to motivate the rehabilitees, and virtual rewards during the gameplay are common in exergaming. However, TUIs can be used for remapping outputs of exercises into rewards that are mediated by other devices found from homes (such as change of TV channel or playing a favorite song) and so outputs of exercises can remain perceivable after the rehabilitee has finished conducting them. Using rewards that are not only perceivable during activity can be expected to be more motivating as the results are perceivable longer and to other persons within the same household.

Collaboration
A half of the stroke survivors are not able to perform ADLs independently, and thus there is a need to consider how the caregivers may participate in the activities. Collaboration can also be used for motivating rehabilitees. For example, activities that need synchronization between caregiver and rehabilitee and activities that remap outputs into messages to support network have a great potential.

Adaptability
The systems should adapt to rehabilitees' progression. There are only a very few longitudinal studies that investigate using technology integrated stroke rehabilitation exercises, thus the amount of novelty effect in previous studies is unknown. Based on our literature review, the longest reported stroke rehabilitation period using technology at home is seven months for one participant [3]. That study revealed that there is a need to modify the designs frequently to avoid discontinuation.

The advantage of TUIs is that they can be modified as the rehabilitee advances. The activity can be made more challenging by modifying the physical interface (e.g., the size of the buttons can decrease as a function of increased motoric skills), by decreasing the acceptable completion time or by increasing the number of repetitions. Moreover, outputs of activities can be remapped into other devices according to rehabilitees' interest.

Where the combination of TUIs and healthcare will be in 10-15 years?

Combining TUIs with the megatrends (such as Internet of Things) enable great advancements also in healthcare. More networked sensors and actuators enable more adaptive homes as the users actions can be recorded and analyzed with a higher accuracy. This development allows developing homes to be not only more suitable for rehabilitation (for example a resistance of a door can adapt automatically to the strength of a rehabilitee) but also more preventive.

Internet of Things allows also new possibilities for social relatedness, as perception of others is easier with increased number of sensors and network connections. Moreover, the shapes and input mechanisms of the TUIs can be modified adaptively with 3D printing. Currently, there is a huge lack of stroke rehabilitation possibilities in developing countries [7] and low cost TUIs (e.g. through 3D printing) has a huge potential. Overall, this development in both input and output enables more personalizable and adaptive TUIs that understand the users' rehabilitation requirements more deeply.

Conclusion

This position paper provided our research approach in evidently large and challenging field of stroke rehabilitation. Designing TUIs that are integrated into everyday activities provide an interesting approach for stroke rehabilitation, because the benefits of digital computing can be combined with repetitive activities. For TUIs to become really a part of stroke rehabilitees' day-to-day activities requires successful design of TUIs in terms of input, feedback, progression, collaboration and adaptability.

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