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Rehabilitation Therapists as Software Creators?
Introducing End-User Development in a Healthcare Setting

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ABSTRACT

The authors discuss the feasibility of End-User Development (EUD) for non-information workers in the context of neurorehabilitation. The authors present a three-week long field deployment of TagTrainer, a system that enables therapists to create, share, and use exercises for arm-hand training with a tangible interactive tabletop application. The experiences suggest that therapists are capable and motivated to create content that is tailored to the training needs of their patients. Three key challenges are identified for enabling EUD practices in a clinical setting, which appear to have a broader relevance outside the specific domain of neurorehabilitation: more support for retrieval and sharing of existing solutions developed by end users, guiding end-user developers to ensure usability and software quality for their creations, and aligning with the revenue model of the organization.

Keywords: *End-User Development (EUD), Neurorehabilitation, Non-Information Workers, TagTrainer, Therapy*

INTRODUCTION

End-user development (EUD) is the creation of software by end-users primarily for their own use, modifying or extending the capabilities and functionality of an extant system (Lieberman, Paternò, & Wulf, 2006). EUD can potentially overcome a major challenge facing software designers and developers: anticipating on the immense variety of contexts in which systems are used, the unexpected purposes, priorities, and usage characteristics that often become known only during actual use. EUD seems particularly promising for domains where there is a need for customized solutions, where domain expertise can provide a very high added value through customisation, and where the

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latter transcends parameter setting, a task that is easily left to end-users, extending to tasks that are typically the responsibility of software engineers. Especially where professionals cannot be assumed to have expertise in software development, this goal is very challenging but the potential rewards very high.

Early research on EUD focused on programming language design and the tools that may support EUD practices (e.g., see (Lieberman et al., 2006; Nardi, 1993; Pane, Ratanamahatana, & Myers, 2001)). Less understood is how well such solutions fare in actual use in a professional context. There have been calls for this community to pay more attention to organizational (Mehandjiev, Sutcliffe, & Lee, 2006), and sociotechnical (Fischer, 2011) factors pertaining to EUD adoption. Questions that emerge, and that we set out to answer with our research are: What are the factors that support or hinder the acceptance of EUD? What is the impact of EUD upon users and their work?

One might expect the answers to such questions to be context dependent. Here we focus on healthcare and specifically technology-supported rehabilitation. Healthcare has been suggested as one of the most promising application domains for EUD, e.g., see (Costabile, Maria Francesca, Lanzilotti, Rosa, & Piccinno, Antonio, 2003; Fischer, 2011). One of the factors that make this domain so particularly suitable for EUD is the immense diversity in patients and their corresponding treatment needs. With EUD, healthcare professionals could be empowered to tailor healthcare technology to the needs of their individual patients. For example, MAPS (Carmien & Fischer, 2008) allows caretakers to create prompting scripts for persons with cognitive disabilities. Their rationale is that caretakers, having the most intimate knowledge of patients, can become end-user developers of assistive technology tools. Their ethnographic evaluation study supports the feasibility of EUD in the healthcare domain, but there is little yet known about what factors enable or hinder the creation, use and reuse of software that they create and how EUD is embedded in clinical practice.

Interactive technologies have been making a gradual entry in upper extremity rehabilitation, e.g., after stroke, spinal cord injury (SCI), or for patients with multiple sclerosis or cerebral palsy. Whether as games (Dhillon, Goulati, Politis, Raczewska, & Markopoulos, 2011), rehabilitation robotics (Gelderblom, De Wilt, Cremers, & Rensma, 2009), or otherwise, interactive technologies are seen as a way to reduce healthcare costs, while extending the quantity and quality of the care provided (Jones, Mueller, & Morris, 2010). Despite this prospect and growing research interest, overall one cannot ignore that physiotherapists and occupational therapists are not information workers; they do not rely on ICT for delivering treatment to patients, and are usually not familiar with software development. They spend little time, if any, behind computer screens and the tasks they perform with computers are secondary to their main tasks. In short, therapists are very different from professionals traditionally targeted in EUD research such as accountants, office workers, and software developers, so different challenges and solutions need to be considered.

In the next section we discuss related work. Then we describe TagTrainer, a platform supporting training of upper extremities with tangible interaction, and report on a three-week long case study in which rehabilitation therapists used this platform in actual clinical practice. Finally, three key challenges are identified for enabling EUD practices in a clinical setting, which appear to have a broader relevance outside the specific domain of neurorehabilitation.

RELATED WORK

Sociotechnical Aspects of EUD

There is little prior art regarding the challenges of introducing EUD in the workplace and how to overcome them. One of the few studies that have taken a broader organizational perspective on EUD (Mehandjiev et al., 2006), reports on a survey among researchers and software developers that studied the antecedents of adoption for EUD. They point out the challenges

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of introducing EUD where quality needs to be ensured, arguing that the utility payoff for EUD will be more favourable when software is intended for personal use or for non-critical missions. In this light, introducing EUD in the healthcare domain presents higher than usual demands regarding quality and effectiveness. Further, Mehandjiev et al. (2006) argued for the importance of fostering supportive communities of developers, end users, and experts, who will share problems and solutions, but did not go as far as attempting to do so. Kierkegaard & Markopoulos (2011) surveyed attitudes towards EUD of rehabilitation workers. They emphasized how these workers are motivated by their drive to serve patients and how remote software creation is to their frame of mind and daily practice. They suggested making benefits for patients the driving force for introducing EUD and that peer recognition rather than material rewards may be a larger motivator for therapists to create software.

A related perspective is that of meta-design (Fischer & Scharff, 2000), which advocates a role shift for designers towards meta-designers: designers of open systems that can be modified by users at use-time. Meta-design systems are seen as instrumental to the emergence of cultures of participation: cultures in which people are enabled to *"actively participate in personally meaningful problems in ways and levels that they are motivated to do so"* (Fischer, 2010). These two perspectives have been developed inductively and iteratively through repeated efforts to empower communities of end-users and have inspired numerous research efforts including the present work. However, there is little empirical evidence of how well these frameworks address the needs of professional domain experts and especially the extent to which EUD practices actually emerge in this domain.

End User Programming of Tangible User Interfaces

Perhaps the first attempt to support EUD for tangible interaction is reported in van Herk, Verhaegh, and Fontijn (2009), which focused primarily on supporting non-programmers to write software at three levels: A graphical environment allows the easy composition of software from simpler building blocks; it provides limited flexibility and is aimed at 'laymen'. A textual macro language provides more power and is aimed at domain experts. Finally, software experts can extend the macro language by coding at a 'kernel level'. van Herk et al. (2009) argued that domain specialists were able to write software using ESPranto and the graphical layer, but focused only on overcoming the cognitive challenges of novice programming out of context, and did not attempt to introduce EUD practices as part of professional practice. Another technology that can support EUD for tangible interaction are Sifteo cubes Merrill, Sun, and Kalanithi (2012), but they do not target non software experts and related EUD practices have not been studied empirically.

Tangible Rehabilitation Technology

Multiple implementations of tangible rehabilitation technology have been reported on, mostly involving the use of (multi-touch) tabletops e.g., see Annett et al. (2009), and Mumford et al. (2008). However, none of these technologies offer an end-user extensible solution that allows therapists to engage in the modification of existing, and creation of new content for such system. For the specific domain of upper-extremity rehabilitation the need to address individual patient needs through customisation and adaptation of rehabilitation technology is well understood, see Timmermans, Seelen, Willmann, and Kingma (2009). While customisation and adaptation of exercise parameters are quite common, there is as yet no example of a system that supports patient specific training content. Where customization has been claimed, e.g. (Alankus, Lazar, May, & Kelleher, 2010), this referred to calibrating the range of movement of a patient rather than the exercise purpose and content, and the calibration was done by system developers of the system rather than the therapists.

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Tag-Trainer

TagTrainer is a tangible, interactive training platform for arm-hand rehabilitation therapy. It allows therapists to run exercises that offer visual and audio feedback, while monitoring a patient's task performance. It is aimed at supporting *task-oriented training* that focuses on relearning Activities of Daily Life (ADL) in their actual complexity rather than the isolated training of different movement ranges or muscle groups as is common with most existing rehabilitation technologies. Thus, TagTrainer exercises involve the manipulation of everyday physical objects such as cups and cutlery to carry out typical ADL activities. TagTrainer consists of four parts:

1. **One or More TagTile Boards**: Interactive boards (24cmx24cm) that can give visual and audio feedback, and are able to detect RFID-tagged objects (see Figure 1). The board provides feedback through full-color LEDs in each square, as well as the possibility to playback audio.
2. **The TagTrainer Patient Interface (TTPI):** Which manages personalized *exercise programs* (i.e. series of exercises) and provides feedback to patients about their progress.
3. **The TagTrainer Exercise Creator (TEC):** which supports authoring and modification of exercises to be executed on the board (see Figure 2).
4. An extensible and customizable collection of **objects** with RFID-tags attached to them.

An example exercise that could be performed with TagTrainer is one where the patient trains wrist rotation in order to be able to drink from a cup. In this case, a therapist would attach a RFID-tag to the bottom, left and right side of a cup. The exercise could then be as follows:

1. An area lights up at the center of the board, indicating to the patient that the cup needs to be placed here.
2. Once the cup has been correctly placed, another area lights up in a different color, indicating to the patient that the cup needs to be turned on its right side in order to touch the lit-up area.
3. Finally, yet another target area lights up, requesting the patient to touch the board with the left side of the cup.

TagTile Board

The TagTile board consists of a grid (24 x 24 cm) of 12 by 12 squares (see Figure 1). Each square can detect the identity and position of RFID-tagged objects. Also, the board provides feedback through full-color LEDs in each square, as well as the possibility to playback audio. A pre-production version of the board has been used earlier to create training solutions for patients with stroke (Timmermans et al., 2010) and children with cerebral palsy (Dhillon et al., 2011; Li, Fontijn, & Markopoulos, 2008). The TagTile board can be programmed by writing scripts in the proprietary ESPranto language (van Herk et al., 2009). The board is connected to a laptop running TagTrainer software, which controls the upload of ESPranto programs to the TagTile board through the TagTrainer Patient Interface. TagTrainer allows therapists to combine up to four TagTile boards in order to increase the training surface.

TagTrainer Patient Interface

The TagTrainer Patient Interface (TTPI) allows therapists to manage patient-tailored *exercise programs*, which consist of a series of *individual exercises*. A patient can use the TTPI to start a personal exercise program and perform the exercises contained in that program. During the execution of the exercises, the TTPI gives the patient progress feedback.

TagTrainer Exercise Creator

The TagTrainer Exercise Creator (TEC, see Figure 2) allows therapists to modify existing exercises, as well as create new exercises for the TagTrainer platform. Exercises that are

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Figure 1. A TagTile board, with a target area lit up blue

created with TEC are converted to ESPranto byte code, so that they can be executed on the TagTile board.

TEC was created in a participatory design process involving therapists and clinical researchers experienced in stroke rehabilitation. An early version (see (Hochstenbach-Waelen, Timmermans, Seelen, Tetteroo, & Markopoulos, 2012)) had been developed to support the creation of arm-hand training exercises on the TagTile board by non-programmers. An extensive usability evaluation of that version of TEC (see (Hochstenbach-Waelen et al., 2012)) showed that, although end-users were able to modify and create exercises, they were often confused by the workflow offered and the terminology used. While TEC did not require writing program code as such, the mental model underlying the initial TEC reflected the underlying programming constructs, even requiring therapists to think about parallelism and other programming constructs. As therapists describe a therapy exercise in terms of physical objects on which manipulations are performed by the patient, TEC was revised to support operations that match this mental model.

The exercise model used in the current version of the TEC is centered on physical objects, as for example the cup in Figure 1. TEC exercises are built around one or more objects on which a patient needs to perform actions of spatial movement such as (de)placement and rotation. The therapist creates a simple model of the exercise using TEC, as a sequence of movements between target areas on the board and repetitions thereof. In principle, any number of objects can be used within an exercise and an unlimited amount of actions can be added to each of the objects. In addition to the object-related actions, instructions, pauses and sound can be added to an exercise (see Figure 2–D, E).

TagTrainer aims to present a low-threshold for new users while still accommodating for the creation of relevant and engaging training content. Complex control structures are not supported and only sequential, stepwise execu-

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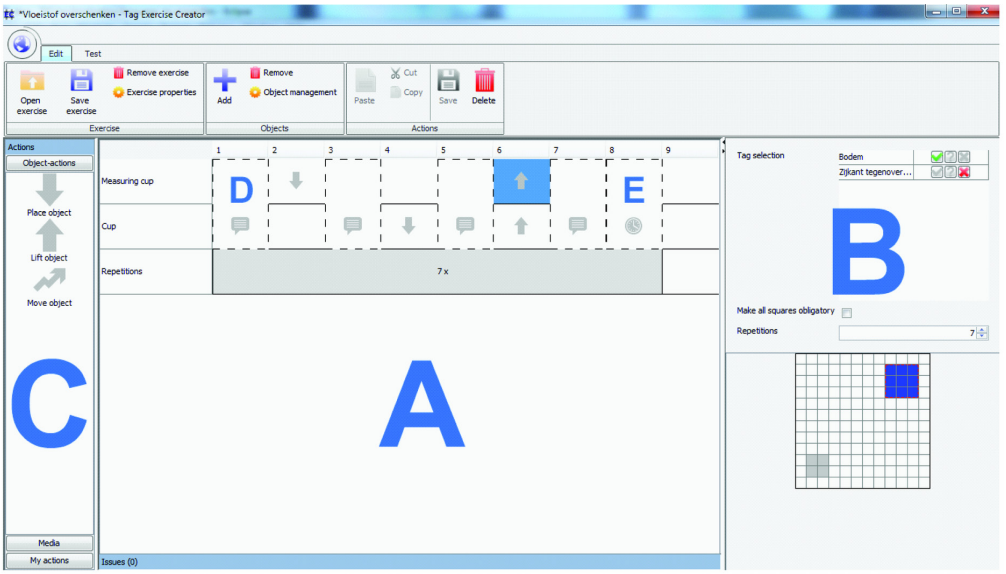
Figure 2. The TagTrainer Exercise Creator (TEC) software. The center area (A) shows the workspace with the exercise, featuring a timeline with actions associated with the objects ('measuring cup' and 'cup') involved in the exercise. Properties of the selected action (in this case 'lift object') such as position on the board are displayed to the right (B). Finally, additional actions can be dragged from the library (C) into the workspace to extend an exercise. Note that beyond actions involving manipulations on the board, other actions such as giving instructions (D) and pausing (E) can be used.



tion of actions is possible. For example, actions scheduled to occur in step 2 of an exercise can only happen after the first step has been completed. However, (parts of) an exercise can be repeated to increase training intensity. Users are further aided by an automated validation tool that notifies them about errors or inconsistencies in their creations. Errors by patients in the execution of an exercise (e.g. using an incorrect object) are handled automatically through default routines (such as repeating the instructions for the current step) and need not to be addressed by the creator of an exercise.

Figure 3 shows how TEC can be used to adjust exercises to the needs of individual patients. Suppose the exercise is to move a wallet from one place on the board to another. Figure 3-1 shows how the exercise can be adjusted for patients with lesser arm-hand function. From requiring a patient to lift the wallet from the TagTile board (step 3), move it and put it down (step 4), the exercise is adjusted to allow the wallet to be pushed towards the target destination. Figure 3-2 shows how the exercise can be made easier by enlarging the size of a target area on the TagTile board.

Tangible Objects

The main distinguishing feature of TagTrainer compared to other rehabilitation technologies is that it enables the use of everyday objects in training. A collection of such objects are provided with TagTrainer and can be extended by the therapist using objects relevant to patients' training needs or even objects that belong to patients. Objects or specific object parts need only to be equipped with one or more *tags*. A tag helps detect when an object or a specific part of an object (e.g., its top or bottom face)

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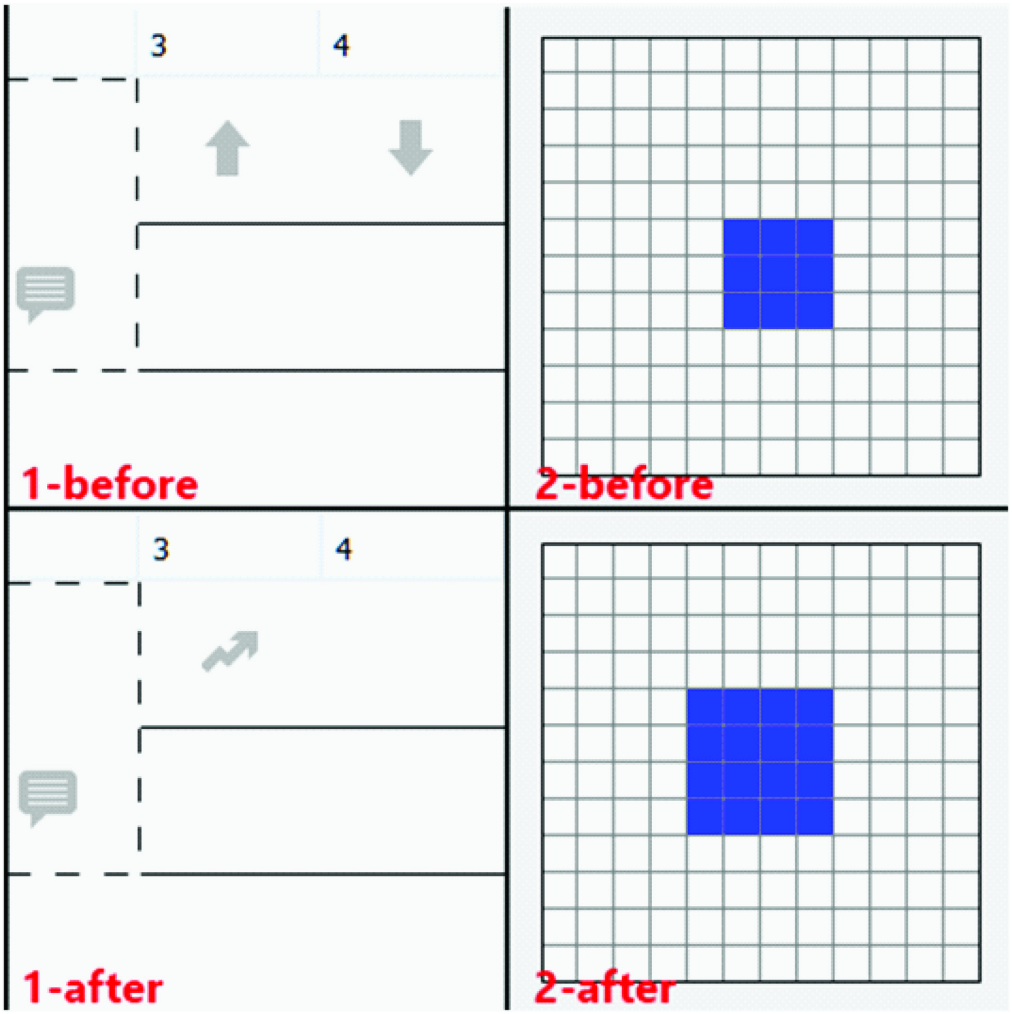
Figure 3. Two examples of how TEC might be used to modify an exercise 1) by using different actions, and 2) by adjusting the size of a target area on the TagTile board



is placed on a specific location on the board. In the initial TEC system (Hochstenbach-Waelen et al., 2012) tags were identified by a unique identifier code, which made programming them cumbersome. In the new version, tags consist of a piece of colored foam and a piece of Velcro-tape, with the RFID-coil glued in between. In creating the exercises, tags are referred to by their color, which provides an abstraction layer that hides RFID-tag management from users. The default tag-library contains ten different colors, but can be extended when necessary. With the tag-library, TEC users only have to assign tag colors to objects or object parts that should be detected by the board.

An Action Research Intervention Study

Going beyond a usability evaluation study (as in Hochstenbach-Waelen et al. (2012)), the present study was aimed at identifying and understanding factors influencing the adoption of EUD practices in the workplace, the

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feasibility of EUD in the context of a rehabilitation clinic, and how technical aspects of the TagTrainer influence or hinder this feasibility. Patients' experiences and the clinical validity of TagTrainer have not been researched within the present study.

Method

An Action Research approach was adopted that combines both action and research within the same process and aims at generating knowledge by improving practice, and improving practice by applying knowledge (Anderson & Herr, 2005). This approach fits the dual aim of the study: (1) the action aim of introducing TagTrainer in arm-hand rehabilitation practice, and (2) understanding issues surrounding the adoption of TagTrainer and EUD. Therapists and clinical researchers from the clinic where the study was held were involved in the design of the study, monitoring its progress, interpreting, presenting and reporting the results.

The study lasted three weeks and was carried out at a rehabilitation clinic (Adelante Centre of Expertise in Rehabilitation and Audiology, Hoensbroek, The Netherlands). Three occupational therapists and one physiotherapist (2m, 2f) participated in this study; two highly specialized in arm-hand training of stroke patients and the other two in spinal cord injured (SCI) patients. Our participants were considered to be innovators, or early adopters (Rogers, 1995) (of new forms of rehabilitation therapy) within the environment of the clinic. They participated voluntarily and did not receive any incentives, besides the possibility to learn about and work with a new technology for rehabilitation. The management of the clinic freed them from a part (1 hour per week, per therapist) of their regular workload to participate. Note that the decision of whether or not to use TagTrainer was left entirely to the therapists. Even if TagTrainer training would be suitable for a particular patient, a therapist could still decide to apply a different training method.

The study was divided into two phases. The first 'use phase' lasted for the first week of the study, during which therapists could integrate TagTrainer in their daily arm-hand therapy programs. Therapists were provided with an initial set of about 150 exercises (i.e. a 'seed' (Fischer & Giaccardi, 2006)). Although they were allowed to modify existing exercises or create new content for TagTrainer, this was not yet actively encouraged. The second phase of the study, the 'creation phase', lasted for the remaining two weeks, during which therapists were actively encouraged to become creators of therapy content.

True to action research methodology, the study consisted of consecutive cycles of research and action. During twice-weekly meetings (lasting 30 minutes) the individual therapists were encouraged to discuss any problems, requests or remarks concerning the TagTrainer system or the interpretation of the results. The meetings were usually followed by an action cycle, in which change requests were processed into the software as well as into the design of the study itself. Support for the TagTrainer system by the researchers was available to the therapists for the entire duration of the study.

Measures

An essential factor in any technology adoption process is the extent to which users believe to be able to use it. Self-efficacy directly affects intent (Ajzen, 1991): if a therapist feels (s)he has not mastered the TagTrainer system, (s)he will be less likely to use the system, let alone create new therapy content with it. A self-efficacy questionnaire (scaled 0-100, based on (Bandura, 2006)) was administered at three moments during the study: right at the start of the study, after one week and at the reflection session at the end of the study.

At the same moments in the study the UTAUT questionnaire (7-point scale, see Venkatesh, Morris, Gordon B. Davis, and Davis (2003)) was administered to evaluate technology acceptance among participating therapists, and its determinant factors such as: ease of use, usefulness and social norms.

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The first author embedded himself in the clinic for the duration of the study as a participant observer. Written notes and pictures were taken during observations focusing on the context of use (type of patient, individual or group therapy, etc.), the mode of use (exercises executed, objects used, etc.) and organizational issues (setup of TagTrainer system for therapy, other activities during TagTrainer use, etc.). Semi-structured interviews were held with therapists during individual feedback sessions and two group feedback sessions. These interviews covered several topics: the usability of TagTrainer, usage patterns and even the structure of the study itself. These feedback sessions were also used to discuss the interpretation of any observations with the participating therapists.

Finally, usage of TagTrainer was logged to obtain objective measures of usage, information on patients, and to create a record pertaining to how and which exercises were created, executed, or modified.

In order to ensure the reliability of the conclusions drawn, the analysis and data collection were carried out iteratively and preliminary conclusions were immediately checked either in follow up interviews or by effecting changes to the software and evaluating those changes. Further, transcripts of interview and observation notes were subjected to qualitative analysis.

Findings

For anonymity and legibility, we refer to participants by pseudonyms: Tim and Tiffany (specialized in stroke rehabilitation), and Marc and Mary (specialized in SCI rehabilitation).

TagTrainer Usage & Reception

One TagTrainer system was installed in the treatment room for stroke and another in the room for SCI patients. 13 different patients have trained with TagTrainer (10 stroke patients, three SCI patients) in 34 therapy sessions, about 25% of all arm-hand training sessions given by the participating therapists during the study. Therapists selected patients to work with TagTrainer based on whether TagTrainer offered a sensible training solution given their specific problems and state of rehabilitation.

Therapy at the participating clinic is given individually, but also in groups of patients having similar skill levels. Out of the 34 sessions in which TagTrainer was used, 20 sessions were group therapy; the other 14 were individual therapy sessions. During some group therapy sessions multiple individual patients worked with TagTrainer, so the number of treatments with TagTrainer is higher than the number of sessions in which TagTrainer has been used. The therapists' attitude towards TagTrainer was positive (M=5.60, SD=0.67) and they intended to continue using the system after the study (M=5.50, SD=1.23), which is a positive outcome for the 'action' component of the research.

Self-Efficacy

Results from the self-efficacy questionnaire show a significant increase in self-efficacy between the start (M=52.3, SD=37.6) and the end (M=75.4, SD=19.1) of the study ($t(3)=-2.356$, $p=0.05$). In general, therapists reported moderate to high self-efficacy, except for their perceived ability to resolve technical problems with TagTrainer (M=32.5, SD=28.7). Self-efficacy scores on key EUD tasks such as modification (M=45.0, SD=52.6, resp. M=77.5, SD=28.7) and creation (M=45.0, SD=52.6, resp. M=82.5, SD=23.6) of therapy exercises increased towards the end of the study.

Created Content

Therapists modified three existing exercises and created 20 new exercises. Modifications ranged from parameter adjustments (adjusting target area sizes) to structural changes (adding extra steps to an exercise). New exercises ranged from derivatives from existing exercises to completely new content. An example of the latter, Mary created an exercise training sandwich preparation, in which the patient has to put a sandwich on the board, pick up a knife and cut the sandwich (see Figure 4). For this exercise not only new software, but also a new hardware artefact (a foam sandwich) was created.

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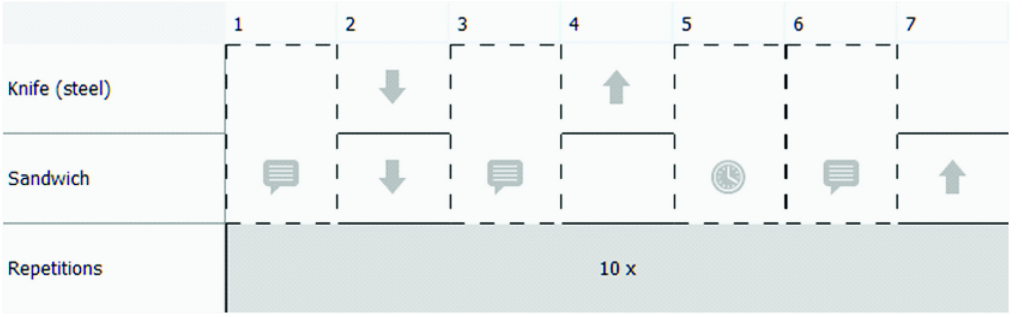
Figure 4. 'Sandwich cutting' exercise created by a therapist. The exercise features two objects ('knife' and 'sandwich') that have been tagged. The patient receives an instruction to put both objects on the TagTile board, after which the patient is instructed to pick up the knife. Then, the patient is instructed to use the knife to cut the sandwich. Finally, the patient is instructed to lift the sandwich from the board. For increased training intensity, the exercise is repeated ten times.



Newly created exercises frequently displayed usability problems. An example relating to the before mentioned exercise, a visual confirmation shown to the patient upon correctly placing the sandwich on the board would remain invisible due to the sandwich covering it entirely. Often, such usability flaws were only discovered during actual therapy, causing patients to get stuck in an exercise.

A closer look at the data reveals relatively large differences in self-efficacy scores related to EUD tasks (i.e. modification and creation of exercises) among individual participants. Tim scored low on self-efficacy and although his score improved towards the end of the study, it was still lower than that of Marc and Mary. Tim explained:

The actual creation of the exercise is not a real problem, but getting the right mind-set to translate from 'what does this patient need' to 'how can I design an exercise for this on the board': that's the part that I found to be difficult.

EUD Practices

Participants were introduced gradually to features of TagTrainer. A workshop about how to modify or create therapy exercises was given at the start of the second week of the study. However, during the kick-off meeting at the start of the first week of the study, therapists indicated that they were particularly keen to learn these skills. Still, they did not apply their newly learned skills directly afterwards: Out of the twenty exercises created during the study, twelve were created during its last week.

According to participants, the major hindrance for creating exercises is lack of time. Typically, it would take a therapist between 5 and 30 minutes to create a new exercise, including time needed to retrieve and prepare the required tagged objects. Their working schedule leaves little or no time at all for auxiliary tasks – here, the creation or modification of therapy exercises. Still, therapists managed to create 20 new exercises, mostly during time that was not reserved for patient contact, such as during feedback sessions, breaks, and after-hours. Individual therapists created between four (Tim and Marc) and seven (Tiffany) exercises each. The TagTrainer logs, as well as the therapists themselves reveal different levels of engagement in creating exercises. For example, Tim gradually slipped into a consumer role (Fischer & Giaccardi, 2006):

I guess I'm the slowest of our group [...], creating a new exercise takes me almost 30 minutes, which I cannot spend on patient care.

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While therapists' main motivation for using TagTrainer was uniform, namely to improve the training quality, their line of thought for creating new exercises displayed subtle differences. Marc and Mary stated that they would only develop new exercises that would match the requirements of a specific patient. For example, if a patient would express the wish to relearn the activity of window cleaning, they would think about a way to implement an exercise with TagTrainer that could support this activity. In contrast, Tiffany's starting point was technology-focused and she was motivated to explore the possibilities of TagTrainer. She would, keeping her patients in mind, start by identifying objects that could be interesting to work with in combination with the TagTrainer system:

While driving home yesterday, I was thinking about what objects I could use with the TagTrainer system. Then I thought of creating exercises with a book, which would suit for example [name of patient].

Sharing and Reuse

Sharing the exercises that therapists create can potentially provide for a much higher variability of exercises than any individual therapist can offer to a patient and provide efficiency gains. In this study therapists had just one TagTrainer system available per pathology, so they always had to share their system with just one colleague. Since exercises were stored locally, all created and modified content was easily shared between pairs of therapists working with each patient group, without the need for any explicit action. Explicit sharing, intentionally initiated by therapists towards their colleagues, happened only during group feedback sessions.

Especially for stroke training, therapists were often unaware about the exercises that their colleague had modified or created. However, for SCI training, due to the prominent position of TagTrainer within the training room, therapists regularly noticed occasions in which the other therapist was applying a self-created exercise in therapy. This had a two-fold benefit: On the one hand, they learned about the availability and application of new exercises that had been developed by their colleague. On the other hand, it stimulated them to create new exercises themselves.

The 20 exercises that were created by the participants were used 76 times. In 11 of these cases an exercise was used by another therapist than its creator. One of the issues that arose during the study was that therapists found it hard to understand the exact nature of exercises available. As Tiffany remarked:

I find it difficult to use the system in therapy, since I don't know exactly what all of the exercises entail. Just a name and a description are not enough for me to estimate, for example, how long a patient would take to complete an exercise.

Discussion

At the end of the three week study, all four participating therapists had engaged successfully in the creation and modification of exercises, as part of actual treatment. Moreover they were overall positive of the experience and were set on using the system. However, therapists varied in how they engaged as creators of therapy content. They gradually took on different roles, either (re-)using or creating exercise content, a pattern known from crowdsourcing communities (e.g. Wikipedia) and as anticipated by the cultures of participation theory (Fischer, 2011).

While there have been earlier attempts to apply EUD in the domain of healthcare, e.g. (Carmien & Fischer, 2008), little is known regarding the feasibility and challenges of inserting EUD in healthcare practice. In this study it became clear how focused health professionals are on patient care and how this determines the applicability of EUD practices in several ways. We identified key three challenges for enabling EUD practices in a clinical setting: aligning with the revenue model of the organization, guiding end-user developers to ensure usability and software quality for their creations, and

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providing support for retrieval and sharing of existing solutions developed by end users.

Aligning with the Clinic's Revenue Model

Physiotherapists and occupational therapists will not divert time from patients to programming and do not spend much time behind a computer anyway, so the threshold for engaging in EUD is higher compared to other domains where EUD has been attempted. Seeing how critical time is for therapists it is interesting to consider how it trades off with the utility of the exercises they create. Such a trade-off is captured in the attention investment model by Blackwell (2002). However, this model is limited in that the decision to write a program is framed as an investment equation, in which the expected payoff is compared to the investment and risk in terms of 'units' of attention. In the present case though, the utility of creating exercises extends beyond therapists' attention to improving the motivation of patients, the intensity and the relevance of training to their lives and enabling semi-independent training and group training.

Ensuring the Quality of Creations

Therapists do not have expertise in interaction design and might be unable to provide the level of usability that is required by their patients without sufficient expert guidance. While more pronounced in this domain, this issue is of general importance and pretty much overlooked by current EUD literature. Further to usability, the quality of the software created is of particular importance as inefficient or incorrect software creations might potentially harm patients or at least fail to provide them any benefit. A challenge in the domain of rehabilitation is that training content has to bear two levels of correctness: software quality (i.e. being 'bug-free' or being usable as e.g. by Fisher,II et al. (2006), and Rothermel, Burnett, Li, Dupuis, and Sheretov (2001)) and clinical effectiveness (i.e. helping rather than hampering a patient's recovery process). A possible solution could be a system in which therapists rate creations of their peers or an external body certifies created exercises.

Facilitating Sharing and Reuse

One of the cornerstones of the TagTrainer system is the possibility to share and reuse the exercises users create or modify. Therapists can provide patient tailored treatment, without themselves having to invest time on conceptualizing and programming training exercises. Two surprising findings from this case study are that therapists were inclined to create entirely new exercises rather than to modify existing exercises. One explanation is that participants could not efficiently evaluate the applicability of training content created by their peers for treating their own patients (i.e. the perceived costs of reuse were higher than the perceived benefits (Blackwell, 2002)). While one could hastily dismiss this problem as an interaction design limitation that could be improved with iteration, it remains that supporting searching, browsing, and retrieving earlier of solutions is a key enabler for software reuse and one that is so far not explored systematically in the field of EUD.

The difficulty in re-using code and sharing code between programmers is well known (Haefliger, Krogh, & Spaeth, 2008), and has motivated engineering practices such as component based software development (Szyperski, 1998), API usability (Daughtry, Farooq, Stylos, & Myers, 2009), and at a more operational level commenting and documentation of source code. However, it is questionable whether such engineering practices could be expected by professionals whose main responsibility is not software development. Even in the case of what Segal calls 'professional end-user developers' (i.e. "people who work in highly technical, knowledge-rich domains and who develop software in order to further their professional goals"), such practices are uncommon and the perceived costs of these practices are greater than their benefits (Segal, 2007). Moreover, there are major differences to how therapists

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will explain an exercise, versus what could constitute a suitable documentation of the relevant software. Results from this study show that indeed one of the most prominent problems that therapists encountered in the exercise creation process was the translation between different 'languages' applying to their problem: i.e. handling the translation between intrinsic meaning (what does the exercise do?), programming language (how was it built?) and natural language (how can I explain it to a colleague?), see also de Souza, Garcia, Slaviero, Pinto, and Repenning (2011), and Pane et al. (2001)).

Caution should be exercised in interpreting and generalizing the findings from this case. The provision of technical support by the research team, which was necessary to achieve the impact aimed for, is not easily available in other clinics. Adoption of EUD in other contexts might thus be more challenging, pointing to the need to provide an alternative support infrastructure, such as a peer support community in line with the vision of meta-design and of cultures of participation discussed by Fischer (Fischer & Scharff, 2000; Fischer, 2010). Our future work shall investigate what role a supportive community (i.e. (Fischer, 2010)) could play in addressing some of the challenges identified regarding EUD in a clinical setting. For example, if a community with members at different levels of EUD engagement (e.g. users, modifiers, creators, etc.) would exist, what impact would this have on the members' perception of EUD tasks?

A relevant issue that needs to be studied more is how to support and encourage sharing of exercises created. Support for sharing in this case study was very much tied to the specifics of the research setting: a small number of therapists physically sharing machines and thus content pairwise. We would like to extend our investigation to evaluate the feasibility of sharing when therapists are distributed using different machines, in different rooms, or different clinics altogether.

CONCLUSION

This paper has demonstrated the feasibility of EUD of tangible and embodied interaction and especially in the domain of physical rehabilitation. While there have been a few limited attempts to support EUD of tangible interactive systems, none has shown the feasibility of this approach involving professional end-users. There have been very few examples of EUD in healthcare, though not for tangibles, none before in the domain of physical rehabilitation and none focussing on the sociotechnical issues surrounding the adoption of EUD.

TagTrainer is an advance in the field of upper extremity neurorehabilitation. By using EUD techniques, the technology offers a high level of customizability to therapists and thereby supports patient-centred treatment more than existing rehabilitation technologies.

This research has identified patterns pertaining to usage, motivation of therapists, and the development of their self-efficacy as creators. It has also identified factors that need to be addressed for EUD to be viable in the rehabilitation domain, particularly with regards to facilitating re-use of software developed by different users, a challenge that has been overlooked by EUD research so far.

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