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Designing for Lived Informatics in Out-of-Clinic Physical Rehabilitation

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In this article we focus on how rehabilitees make use of personal data as part of performing their prescribed physical therapy in out-of-clinic settings (e.g., home). Over the past 5 years we have been extensively involved in the design of pervasive and mobile technologies to support out-of-clinic physical rehabilitation. Two strands guide our work: situated and embodied interaction, and the practice and theory of physical rehabilitation. In particular we draw upon the latter's practice of integrating therapy with the lived everyday settings and the model of Person–Environment–Occupation. We revisit this work from the emerging perspective of lived informatics to bring forward multiple instances of rehabilitees using personal rehabilitation data to make sense of their physical rehabilitation process. We present these instances under four categories: becoming your own standard of reference; marking your life as a rehabilitee; articulating with therapists, partners, and peers; and incorporating exercising with everyday activities. We put forward the Person–Environment–Occupation model as a generative entry point for designing digital technology in support of lived informatics in out-of-clinic physical rehabilitation. Through this article we invite researchers in the field of lived informatics to engage in the design of digital technologies for out-of-clinic physical rehabilitation.

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CONTENTS

1. INTRODUCTION

> Rehabilitation: A goal-oriented, cooperative process involving a member of the public, his/her relatives, and professionals over a certain period of time. The aim of this process is to ensure that the person in question, who has, or is at risk of having, seriously diminished physical, mental and social functions, can achieve independence and a meaningful life. Rehabilitation takes account of the person's situation as a whole and the decisions he or she must make, and comprises co-ordinated, coherent, and knowledge based measures. (Definition from the National Danish Whitepaper on Rehabilitation, 2004)

Positioned in the intersection of ubiquitous computing and interaction design we have, over 5 years, conducted a series of interaction design research explorations seeking to uncover ways in which digital technology can be designed in support of out-of-clinic physical rehabilitation. Using design interventions as the primary research vehicle and working closely with rehabilitees and rehabilitators, we have in parallel sought to gain an understanding of the existing practices of physical rehabilitation as well as an understanding of the future opportunities for technology design. As such, our work and the findings we present are the result of a constant movement back and forth between today's established practices of physical rehabilitation and enactments of what could be the practices of tomorrow. Our research is strongly influenced by the theory of embodied interaction (Dourish, 2001) emphasizing the situated and circumstantial nature of human action throughout our design. In the article at hand, we revisit our work while keeping a particular eye on the multiple roles played by personal rehabilitation data as part of physical rehabilitation practices—existing and envisioned.

As pointed to by the definition, rehabilitation implies that a rehabilitee (the person undergoing rehabilitation) through a process of rehabilitation in a very broad sense can reclaim his or her abilities to participate in everyday life and society. As such, rehabilitation processes and therapeutic interventions address a vast range of conditions and circumstances of the individual rehabilitee with overall improvements of the rehabilitees quality of life as the top-level measure of a success. As is discussed further in this article, we have throughout our close collaboration with practitioners and researchers in the field of rehabilitation encountered a strong constructive alignment between our theoretical foundation in the phenomenologically informed theory of embodied interaction and the theoretical foundation underlying the approach of analysis and intervention carried out as key to the work of occupational and physiotherapists.

In particular, we experienced a shared "worldview" and perspective on the interplay between humans, the activities they perform, and the particularities of the social and physical setting embedding these activities. This alignment of worldviews across disciplines allowed for a shared holistic understanding of what it means to intervene in a rehabilitee's life world when looking to improve quality of life and in turn a shared understanding of how and what the role of mobile and pervasive digital

technologies might be as part of such interventions. We discuss this alignment further and how it made way for a fruitful collaboration with rehabilitation therapist. Firstly, we outline how we, through our interactions with the physiotherapists, encountered a "working hypothesis" that focuses on integrating the prescribed therapy with the particular everyday settings of the rehabilitees. Toward the end of the article we present a reframing of this working hypothesis as an interaction design challenge. Second, we outline how the tools for analysis and intervention in the field of physical rehabilitation are rooted in the Person–Environment–Occupation (PEO) model (Law et al., 1996), a transactional model emphasizing a dynamic interplay between an individual's everyday activities, the aspirations to increase her quality of life, and the physical and social conditions embedding the rehabilitation process. Toward the end of this article we put forward the PEO model of rehabilitation therapy as a generative entry point for researchers in the field of lived informatics looking to engage in the design of digital technologies for out-of-clinic physical rehabilitation.

Our work in particular concerns the subset of rehabilitation processes directed toward physical rehabilitation. Even if only a subset, physical rehabilitation processes still encompass a diverse set of conditions. Some physical rehabilitation processes are framed as short-term physical training aimed at helping the rehabilitees cope with a temporary disability and perform activities of daily living, such as the 12-week rehabilitation programs aimed at helping rehabilitees regain their walking capacity after hip replacement surgery. Others imply learning how to cope with activities of daily living and other larger aspects such as active participation in civic democracies despite a chronic physical condition such as lower back pain, the loss of a limb, or inborn physical disabilities. In general, the success of physical rehabilitation processes relies on rehabilitee adherence to perform a prescribed set of physical exercises and incorporates strong elements of self-monitoring and self-reflection. Although some exercises are to be carried out within the highly structured supervised settings of a clinic, others are to be performed in the differently structured unsupervised home settings of the rehabilitees.

Regardless of the setting and the physical conditions addressed, the recording and management of personal data are already considered key parts of existing rehabilitation practices. Whether it is the simple jotting down of numbers to keep track during a particular exercise, the keeping of records to self-reflect and/or discuss long-term progress with others, or the authoring of diaries with its rich descriptions of how the rehabilitation process is experienced as part of everyday living, recording and management of data are inherent components of physical rehabilitation. We find that both rehabilitees and rehabilitators have experience with and a well-articulated appreciation of the role and management of personal rehabilitation data. As we elaborate further in this article, this provides a rather unique point of departure when coexploring, with rehabilitates and rehabilitators, the design of digital technologies in support of physical rehabilitation. In particular, it sets the design of personal informatics systems for physical rehabilitation somewhat aside from other "living-by-numbers" projects where the motivation to engage with personal data in the first place needs to be somehow established and argued as part of the projects.

Whether part of established practices or demonstrated by rehabilitee and rehabilitator enactments of future practices we soon realize that the role played by personal rehabilitation data in rehabilitation is multifaceted. Drawing on the theory of embodied interaction we find that the role of personal rehabilitation data is better viewed as part of the interactive processes of meaning-making strongly influenced by, and in turn influencing, the particularities of the physical and social setting in which the rehabilitation processes are embedded. Furthermore, we find that the kind of engagement with personal rehabilitation data we see in our work cuts across any attempt to make a distinct segmentation into production and use of data, or as we often see it discussed in literature on personal informatics systems as a segmentation into the five stages of preparation, recording, processing, display, and reflection (Li, Dey, & Forlizzi, 2010). As such we add to the work on "lived informatics" (Epstein, Ping, Fogarty, & Munson, 2015; Rooksby, Rost, Morrison, & Chalmers, 2014) arguing the need for more nuanced ways to describe how the management of personal data is worked into the mundane activities of everyday living.

In particular, we revisit our design explorations, using anecdotes that resonate with the notion of lived informatics, and identify different roles of personal rehabilitation data all pointing to the rich and entangled ways that these data are "used" as part of the "lived" physical rehabilitation processes we have encountered. Our examples highlight how the rehabilitees participating in our design explorations enacted and envisioned multiple uses of their personal rehabilitation data. Namely, these multiple uses were (a) to make sense of the rehabilitees' efforts in relation to their bodies and settings of out-of-clinic rehabilitation; (b) as visual and material markers part of the rehabilitees' living environments that reminded them not only about their exercises but also in general about their life as people undergoing physical rehabilitation; (c) to sift, sort, and select aspects of their lives as rehabilitees and share with their therapists, family members, and peers; and (d) to turn their everyday activities into an opportunity for performing the exercises prescribed as part of their rehabilitation. We present the instances of the multiple uses of personal rehabilitation data in four categories: (a) becoming your own standard of reference; (b) marking your life as a rehabilitee; (c) articulating with therapists, partners, and peers; and (d) incorporating exercising with everyday activities.

Our contribution is threefold:

1. By revisiting our work from the perspective of lived informatics we bring forward a nuanced understanding of lived informatics in the context of current and future practices of out-of-clinic physical rehabilitation.
2. By reframing the working hypothesis of the physiotherapists as an interaction design challenge, we open a space for technology design interventions aligned with the lived practice of out-of-clinic physical rehabilitation, in turn calling for the support of collaborative and individualized rehabilitation practices.
3. By positioning the PEO model as a generative entry point for technology design we invite the researchers in the field of lived informatics to engage in the design of

digital technologies for out-of-clinic physical rehabilitation.

The article is structured as follows. First we outline the working hypothesis and the PEO model as the background knowledge establishing the grounds for the practice and theory of physical rehabilitation. We present the methodology that originally guided our works discussed in this article, as well as the method of revisiting that we now employ to relate to the emerging perspective of lived informatics. We then give a brief presentation of the parts of our design work that we draw from in this article, before presenting the analysis of revisiting in the form of the aforementioned four categories. In the Discussion section we outline how we as interaction designers reframe the working hypothesis as an interaction design challenge and put forward the PEO model as generative entry point for design.

2. BACKGROUND

2.1. Physical Rehabilitation: Working Hypothesis

In general, a physical rehabilitation process involves consultations with professional physiotherapists, who recommend exercise therapies based on the particular diagnosis of the injury. The rehabilitation process also involves periodic sessions at the clinic, where the rehabilitees perform the exercises under the guidance of the physiotherapists. In between these periodic sessions, the rehabilitees are encouraged to adhere with the treatment by performing a set of prescribed exercises at home on a daily basis. Performing the exercises at home is considered a key element of becoming successfully rehabilitated.

Despite the key role that adhering with the prescribed treatment holds for a successful rehabilitation, therapists, however, report a lack of adherence among the rehabilitees when at home. Research (Campbell, Evans, Tucker, Quilty, & Donovan, 2001; Petursdottir, Arnadottir, & Halldorsdottir, 2010; Sluijs, Kok, & Van Der Zee, 1993) has found that it is difficult for the rehabilitees to adhere to their treatment and perform the exercises at home consistently. These studies find that adherence is influenced by multiple factors, including the individual attitudes toward illness and exercises, support from physiotherapists, feedback about progress made, and ability to integrate the exercises with everyday routines within the broader social and physical environments of the individuals.

When rehabilitees find it difficult to adhere to a physical rehabilitation regimen, it leads to an increased cost to the society, particularly in cases where health care is supported and funded by the state (Campbell et al., 2001). A failed rehabilitation process leads to various costs to society. Of particular interest to this article, retired senior citizens may require additional care and support from the public health system in performing their activities of daily living if they are not successfully rehabilitated. The costs to the society may also be in the form of transportation that the clinic has to organize to pick up and drop the rehabilitees for their periodic treatment sessions.

In addition, the state's investment on setting up and running a good infrastructure for physical rehabilitation including, physiotherapists, equipment, transportation, and so forth, will not yield expected returns if the rehabilitation process is not successful. Hence, the challenge is to reduce these costs to society incurred due to lack of adherence to a prescribed rehabilitation process.

Furthermore, in response to an ever-growing number of people in need for physical rehabilitation, we see a strong societal demand for more cost-effective rehabilitation solutions. In particular, there is currently a strong push toward out-of-clinic physical rehabilitation programs where larger portions of the rehabilitation process are moved from the clinic to the private homes of the rehabilitees. This furthers the importance of rehabilitees taking more responsibility and initiative toward adhering to their prescribed rehabilitation process. To address low levels of adherence to prescribed physical rehabilitation (e.g., Campbell et al., 2001), works in the field of physiotherapy (e.g., Mastos, Miller, Eliasson, & Imms, ; McClain, 2005; Nicholls & Gibson, 2010) call for more involvement and engagement of rehabilitees in defining their own rehabilitation regimes and plans.

Turning to the practice of physiotherapists, we observed how their work is guided by a working hypothesis: Integration of physical rehabilitation exercises with rehabilitee's everyday activities will lead to better adherence and, in turn, more successful out-of-clinic rehabilitation. We observed the practices of integration during our work with physiotherapists. Broadly, the physiotherapists prescribe rehabilitation therapy that is conducive for the individual rehabilitee to integrate the therapy with their specific everyday activities, spaces, and objects. An example of the individualized approach, observed from our interactions with professional physiotherapists, is how the rehabilitees receive suggestions about using everyday artifacts as tools for exercising, such as filled water bottles used as weights or a chair used as support for sit–stand exercises. These therapy procedures are arrived at in close collaboration with the individual rehabilitee (McClain, 2005) to develop an understanding of the specific situation of the rehabilitee while exercising at home. The therapists work closely with the rehabilitee to identify specific objects and activities of everyday use by the rehabilitee and suggest therapy exercises that better suits the rehabilitee.

Mastos et al. (2007) described how having specific, achievable goals integrated with an individual's everyday environment will increase the motivation of the individual to engage in the therapy. They identified four components of a goal-oriented physical therapy process, one of which is the setting of goals that are meaningful for the individuals—goals that are tuned to the Activities of Daily Living (ADL) such as walking to the store, picking up a towel, or wearing socks. Notably, a fast-growing area for physical rehabilitation is related to conditions of aging, and hence physical rehabilitation is often a component of aging-in-place programs enabling senior citizens to stay longer in their private homes by sustaining their capability to carry out ADL.

As we discuss in more detail in this article, the move to from the highly structured supervised settings at the clinic to the unsupervised home settings of the rehabilitees has not only challenges but also and more importantly novel opportunities for the design of personal informatics systems in the domain of physical rehabilitation—opportunities that we suggest

are pursued by employing state-of-art pervasive and mobile technologies as enablers in support of lived practice of out-of-clinic physical rehabilitation.

2.2. Person-Environment-Occupation Model

As mentioned, all the design explorations we report in this article were conducted in close collaboration with experts in the area of physical rehabilitation, including practitioners as well as researchers in this field. We encountered the working hypothesis through our collaboration with the therapists. But we soon realized that this hypothesis in fact is informed by a foundational theoretical worldview captured in the form of the PEO model (Law et al., 1996) guiding research, education, and practice in the area of physical rehabilitation.

As we started engaging the therapists in the codesign of digital technologies for physical rehabilitation, we kept being surprised about how positively and with little friction the ideas that we brought to this collaboration were received and further developed by the therapists. At first, we attributed this to the coincidence of working with the particular group of therapists. Later on, however, when we started working closer with researchers and educators in the field of physical rehabilitation we came to realize that the ease of engagement that we had experienced from the therapists was all but a coincidence, and how it was caused by a much more profound preexisting alignment of worldviews that we shared across the disciplines of rehabilitation and the design for embodied interaction.

The shared worldview was grounded in a holistic ecological perspective foregrounding the interwovenness and interdependence of the individual's ability to perform everyday activities and the physical and social setting embedding this performance. Our worldview was informed by the phenomenologically grounded theoretical framework of embodied interaction and the therapists by the PEO model at the heart of therapist work when analyzing and devising interventions for the individual rehabilitees in the meeting with their life worlds.

The International Classification of Functioning, Disability, and Health model put forward by the World Health Organization (2001) is considered a more comprehensive model utilized by the academic field of rehabilitation and disability studies. However, an in-depth comparative analysis of which model is better aligned to the problem at hand is beyond the scope of this article. The physiotherapists we interacted with referred to the PEO model, employing it to guide their practice. And it was their grounding in the PEO model that helped in informing our shared worldview guiding the design explorations. Therefore, in this article we engage with the PEO model as an entry point for design without getting into its merits when compared to the International Classification of Functioning, Disability, and Health model.

In brief, the PEO model encapsulates a transactive approach to analysis and intervention in physical rehabilitation and emphasizes the situated nature of human action and how these actions are fully entangled with the setting—a model reflecting a

worldview that clearly resonates with what we as interaction design researchers in the area of pervasive and mobile digital technologies consider a key part of our foundation.

The PEO model as put forward by Law et al. (1996) has the notion of "occupational performance" at its heart, addressing how an individual with unique capabilities and life experiences performs her occupations in a dynamic interplay with the particular physical, social, and cultural settings embedding this performance. Of particular interest to our work is the distinction between activities, tasks, and occupation. Activities, or rather ADL, are generic actions that people do on a daily basis, such as writing, cooking, walking, lifting weights, and so on. Tasks are purposeful activities, such as writing a report or cooking a meal for four. Occupation are "groups of self directed, functional tasks and activities in which a person engages over a lifespan" (Law et al., 1996, p. 8), for example, being an accountant, a novelist, or a chef.

The PEO model reflects the dominant therapist perspective on the dynamic transactional relationship between the three constituent components —person, environment, and occupation. The model is used throughout therapist practice and training to foreground how the overall ambition is to increase the individual's occupational performance and how the three components can be used as the "entry points" through which the therapist engages in analysis of the individual rehabilitees' current life world. In turn, this analysis leads to a series of recommendations for intervention that in most cases are negotiated with the rehabilitees in order to induce a level of ownership; commitment; and, not least, adherence to the regimen decided on. In this sense we see how the working hypothesis we encountered in our collaboration with therapists was nothing but the PEO model unfolded as part of therapeutic practice. What we experienced could be explained as examples of how the PEO model helps frame the discussion and evaluation of the suggested interventions providing the therapist with a tool for communication.

In terms of methodology, the underlying change-orientation reflected in our research-through-design approach (to be discussed next) found its parallel in the intervention perspective governing the work of the therapists. The therapists were already attuned to a process of dialogic engagement with the particularities of the situation at hand when looking to change the occupational performance of an individual rehabilitee for the better. The familiarity with the setting up of ad hoc experiments to explore, understand, and decide on the appropriate intervention made it straightforward to include the therapists as coexplorers in the type of design-oriented explorative research processes that we were after. We elaborate further on how the PEO model and the match that we have found in terms of worldviews and approaches to engagement can be articulated as generative entry points inviting researchers in the field of lived informatics who want to join research efforts towards the design of pervasive and mobile digital technologies for physical rehabilitation.

3. METHODOLOGY

First we present the methodology that drove our design explorations. Second we discuss the method of revisiting our work from the emerging perspective of lived informatics we employ in this article.

3.1. Construction-Oriented Research-through-Design

Our work follows a construction-oriented research-through-design method (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2012). Each of the explorations was driven by in situ interactive sketching (Buxton, 2007). We sketched in different forms, including software/hardware, video, photomontages, and Wizard of Oz. The sketches were intended as early evocative suggestions of possible solutions to help inspire further coexploration with the rehabilitees, their spouses, and therapists. We took these interactive sketches to the homes of the rehabilitees, asking them to engage in a series of in situ enactments (Brandt & Grunnet, 2000) of how our sketches could become part of their ongoing rehabilitation processes. Also, the sketches were presented to and constantly critiqued by the professional therapists involved in the particular rehabilitation processes in question during the entire process of our design explorations.

Although the design explorations were driven by the in situ process of sketching, our intention was not primarily to address the specific problems of the practices of rehabilitation but rather to theorize about the design of digital technology in support of the self-monitoring practices in out-of-clinic physical rehabilitation. Our focus was to explore if and how digital tools could become a part of the everyday settings of out-of-clinic physical rehabilitation and theorize about this more general question, rather than point to specific technological solutions. In some cases (e.g., in ReWall and ReExercise), it may appear as if the piece of technology we designed was not really "needed" and in fact may complicate the situation. However, the artifacts, or rather interactive sketches, were just that: sketches through which we collaboratively sketched the possibilities of technologies becoming a part of the everyday settings. We do not propose them as solutions but rather as probes for research that bring forward aspects about current and future practices of out-of-clinic rehabilitation and the possibilities of making digital technologies an integrated part of these practices. We were informed by the approach termed as "concept-driven interaction design research" (Stolterman & Wiberg, 2010).

As we outline in the next section, we began our design explorations informed by the theories of embodied and situated interaction, and as the explorations progressed we became clear about what it means to design digital technology in support of the lived, everyday practices of self-monitoring in out-of-clinic physical rehabilitation. This clarity led us to propose and define a theoretical concept, namely, "embodied-self-monitoring." In other words, the theoretical concept and the concrete design artifacts emerged together throughout, and as a result of, our explorations.

Gathering Data for Synthesis and Reflection

The explorations we discuss in this article were driven by closely working with the individual rehabilitees in the actual settings of their physical rehabilitation. In total we worked with four rehabilitees individually. In each exploration, we interacted with the rehabilitees and their therapists or family members over a period of 2–3 months. In the initial sessions, lasting about 2–3 hr and using methods such as field-based observation and semistructured interviews, we observed how each rehabilitee engaged with the particularities of their everyday life in order to perform their therapy. We focused on what kind of objects, activities, and social relations the individual rehabilitee engaged with while exercising at home and outside the boundaries of a clinic. We followed the observation sessions with enactment with interactive sketches at the sites of their rehabilitation, namely, the clinic and home. During the enactment with the sketches, we video-recorded how the rehabilitee engaged with the interactive sketches in combination with other objects, activities, and social relations for performing the exercises. We also recorded what the rehabilitees imagined and enacted about the possible scenarios of engaging with digital technology to shape their ways of performing the prescribed exercises. Each exploration had two to three such sessions of enactment, each lasting 2–3 hr.

We then synthesized these scenarios across the explorations to articulate our understanding of embodied self-monitoring and how this understanding may guide the design of self-monitoring technologies for out-of-clinic physical rehabilitation. We focused on one rehabilitee per design situation as an opportunity for exploring unique possibilities leading to a range of examples of the prospects offered by designing for embodied self-monitoring. We sought uniqueness in each design situation to drive this exploration leading to a range of possible scenarios. In this sense, the four explorations discussed in this article, in their totality, make up the "sample size" for the synthesis.

Revisiting the Design Explorations

To relate embodied self-monitoring to the field of personal informatics, we in particular draw from the more recent notion of "lived informatics." We revisit our explorations to discuss and highlight the multiple roles played by personal rehabilitation data, when engaged with as an integral part of the social and physical settings of out-of-clinic physical rehabilitation. We draw parallels from lived informatics to highlight how our work with embodied self-monitoring can be easily recast as a case of designing for lived informatics in the domain of out-of-clinic physical rehabilitation. As we revisit our work we focus in particular on the diverse ways of using personal rehabilitation data that we encountered as part of the physical rehabilitation processes that we have studied and designed for. We take a fresh look at the rich set of field notes, videos, and images collected during the design explorations. We then identify episodes that explicitly concern the role of personal rehabilitation data as part of the existing as well as envisioned and enacted future practices of physical rehabilitation we have explored.

4. EMBODIED SELF-MONITORING: DESIGNING FOR PHYSICAL REHABILITATION IN CONTEXT

4.1. Embodied and Situated Interaction

As physical rehabilitation moves from clinics into homes, the ways in which rehabilitees perform their prescribed exercises as part of the settings of a home take on an important role (Axelrod et al., 2009; Balaam et al., 2011). How self-monitoring is and could become a part of the everyday settings at home becomes important too. Informed by embodied and situated interaction we focused on how self-monitoring is not a feature to be imbued by digital technology but an ongoing, enacted practice to be designed for.

The theories of embodied interaction (Dourish, 2001) and situated action (Suchman, 2007) informed our work. When seen from the perspective of embodied and situated interaction, a context comes into being, and constantly evolves, due to the interplay between the particular ongoing actions of people and the particularities of the setting within which these actions happen. Embodied interaction is "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts" (Dourish, 2001, p. 126). We read it as a call to explicitly focus on the ongoing action—creation, manipulation, and sharing—as it unfolds, rather than any preconceived mental representation of the action.

Based on this understanding in our design explorations, we focused on the actions performed by the rehabilitees to incorporate the prescribed therapy exercises as part of their everyday activities and settings at home. Furthermore we focused on the interrelationship of the actions and their settings: how the actions that the rehabilitees perform in order to adhere to the prescribed treatment—such as measuring, recording, observing, reflecting, sharing, and so on—are shaped by the particularities of a setting within which these actions are performed, and in turn how these actions shape the setting.

4.2. Embodied Acts of Rehabilitation-in-Context

Taking an embodied interaction perspective when looking at physical rehabilitation activities carried out across home and clinic, we were prompted to focus on the particularities of these settings and how they become very distinct contexts for physical rehabilitation. We focused on how the particular social and material setting at hand become part in shaping how the rehabilitation process unfolds. We focused on the ways the rehabilitees understand their current condition, what they need to do in order to get better, and how to get there through engaging with the prescribed measures, not in isolation but as part of a larger social and material fabric. We understood the rehabilitees' engagement with exercise instructions and tools as situated and circumstantial actions (Suchman, 2007) with which the rehabilitees take advantage of the opportunities for adoption and appropriation of the prescribed measures in

context. Hence, exercise instructions and tools are enacted in situ and in concert with the many other resources for action (e.g., using the particular curve of a chair as a support, or a flight of stairs to perform stepping exercises) that the rehabilitees engage with, in a given setting.

This understanding of rehabilitation-in-context immediately points out the fundamental challenges faced by any attempt to simply box and move a collection of tools, prescriptions, and routines from the structured and supervised setting of a clinic to an unsupervised setting of home (Bagalkot & Sokoler, 2012).

4.3. Exploring the Design in Different Settings of Out-of-Clinic Rehabilitation

In this article we draw from four explorations, namely, MagicMirror, ReSwing, ReWall, and ReExercise. Although we have reported on these explorations before (Bagalkot, 2012; Bagalkot & Sokoler, 2011, 2012, 2013; Bagalkot, Sokoler, & Shaikh, 2012; Bagalkot, Nazzi & Sokoler, 2010), in this article we present a brief outline of each exploration, which is used in Section 5 as the basis for revisiting.

MagicMirror

The MagicMirror explorations were set in the out-of-clinic physical rehabilitation as practiced in and around Copenhagen, Denmark. We focused on exploring the design of digital tools for the rehabilitees to self-record their own exercises at the clinic and home and engage with these recorded videos as references for exercising and collaboration with their therapists.

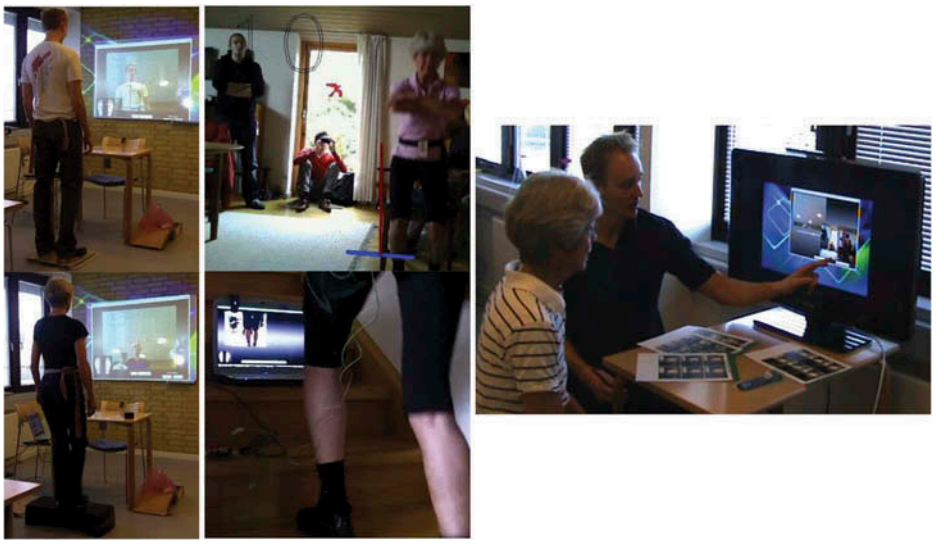
In the first version, we worked with Anita, who was undergoing rehabilitation for a chronic back condition. We video-recorded one of Anita's exercises, namely, upper arm stretches, as she performed them with her physiotherapists at the clinic. We took an edited version of this video, overlaid with visual cues

FIGURE 1. Sketching and exploring video recording exercises at clinic, at home, and back at clinic with Anita.

about the range of her stretching and balance, to Anita's home 2 days later. We asked Anita to perform the exercise by watching this video on a laptop in her living room. We video-recorded her home exercises and brought them back to the clinic, where Anita and her therapists looked at both videos to discuss about the progress made by Anita (see Figure 1).

In the subsequent study, we worked with Anna, who was undergoing a short-term 12-week rehabilitation post hip-replacement surgery, and her therapists. Here we used the Arduino platform to build an interactive version of MagicMirror. Our interactive hard-and-software sketch for this study consisted of a balance board with pressure sensors measuring the weight balance, a belt with an accelerometer for vertical position, a wearable EMG sensor called an "e-patch,"[1] and a digital counter for tracking the number of repetitions of the exercise. Anna performed three kinds of exercises under guidance of Rasmus, her therapist at the clinic. We video-recorded these exercises, and we designed a software application to collect the sensor data and overlay this on the video to give real-time feedback. We followed the same cycle as in the earlier study: We took the in-clinic videos to Anna's home, video-recorded her doing the same exercises at home, and brought the home exercise videos to the clinic as materials for discussion with her therapist (see Figure 2).

FIGURE 2. Sketching and exploring video recording exercises at clinic, at home, and back at clinic with Anna.



[1] http://epatch.madebydelta.com/

ReSwing and ReWall

ReSwing and ReWall were both set in the context of Gita, a 75-year-old woman who lives in a village in central India. Gita was undergoing rehabilitation post knee-replacement surgery. She underwent the surgery 5 years prior in a hospital in Pune, the nearest city, which is a 4-hr bus ride from her town. Since her surgery she has been actively performing the rehabilitation exercises prescribed to her just after her surgery in the hospital, and over time these exercises took the nature of fitness exercises that enable her to be mobile and active rather than corrective therapy exercises. As there is no physiotherapy care near where she lives, she performs the exercises without professional supervision. We chose two of her exercises to explore the design of digital self-monitoring technology that Gita can engage with as an integral part of her rehabilitation practice.

In ReSwing, we focused on a unique exercise that Gita performs. She sits in her garden swing and moves back and forth, flexing her knees, for about 30 min daily (see Figure 3). She has invented this way of exercising, and based on how it has reduced the pain in her knees and how active she has been in performing her household work, she continued to perform the exercise.[2] Because of Gita's ingenuity and her success of being active and independent, her doctor in Pune suggests that other prospective patients visit Gita and understand how they could live with new knee joints. Gita is a leader of a "bhajan mandal," a local folk music group that sings devotional hymns and has won many awards and trophies, which she displays in her living room (see Figure 3). In

FIGURE 3. Gita in her living room with awards and trophies, and exercising on the swing in her garden.

[2] When we met with her doctor in Pune, he did confirm that the exercise is actually beneficial.

FIGURE 4. Gita placing the ReSwing mat on the swing to record data about her exercise, which is displayed in the form of three LEDs on the trophy placed above the television in her living room.

ReSwing, we explored with Gita if and how she could record aspects of her swing exercise and make it a dedicated part of her living room, similar to her musical trophies. We built a mat with an accelerometer that Gita could place on the swing and sit on while exercising (see Figure 4). An Arduino and a Zigbee module sent the accelerometer data to a "trophy" to trigger three LEDs to light up. The LEDs light up for 8 hr after the use of the mat, and then gradually fade out altogether. Text on the trophy congratulated Gita and Kumar, her husband, for successful rehabilitation. Gita experienced the interactive sketch for a week, and we had in-depth discussion about her experiences.

ReWall focuses on another of Gita's exercises. Gita places her back to a portion of a wall in her living room and gently bends her knees to move down and move back up, repeating this 20 times. She performs this exercise at the same spot every day. Gita is also a knitter and has knit many decorative pieces that adorn her living room. In ReWall we explored with Gita if and how she could record the degree of bending she does on a daily basis and display these data as a physical, decorative part of her living room. We took as decorative textile wall piece and fixed two Force Sensing Resistors (FSRs) projecting out of the piece. These were connected to a Lilypad Arduino along with an RGB LED. During her exercise, as Gita brushes across each sensor, it registers her touch and lights up the LED in different colors—green for touching the top sensor and orange for touching the bottom sensor (see Figure 5). We asked Gita to experience this interactive sketch by performing 10 reps of her exercises, and we followed this experience with a discussion.

FIGURE 5. Gita exercising at the wall in her living room, and then experiencing the ReWall sketch while exercising.

ReExercise

ReExercise focused on the rehabilitation of Prabhakar, a 78-year-old man who suffered a stroke 2 years prior to our exploration. Prabhakar lives with his wife in a two-room apartment in a senior citizen colony in a Mumbai suburban area. Prabhakar's mobility is restricted within his apartment, and he has to perform exercises twice a day to strengthen his back and upper body. He performs these exercises on a bed in the living-cum-bedroom, which also acts as a couch for seating visitors and as his bed at night. We observed that Lakshmi, his wife, is constantly around him, supporting him and reminding him, when he exercises. During our exploration we encountered, in a somewhat dramatic fashion (refer to Bagalkot, 2012, for more details), how they are distressed that their four sons do not talk to them. We observed how the couple has become ever more religious as a way to deal with their distress; they prayed twice daily and watched religious TV channels, and the walls were adorned with images of gods and goddesses.

Guided by embodied self-monitoring we embraced the way the couple practiced their religion. In particular, we explored if and how the couple could integrate exercising with praying. We built an exercise mat with an FSR connected to a Lilypad Arduino. We connected an LED to the Arduino and fixed it on a small idol of Ganesha (see Figure 6), the elephant god worshipped by the couple. The FSR measured the force exerted by Prabhakar's elbow while exercising and displayed it in the form of varying brightness of the LED. The LED lit up every time Prabhakar exercised and shut off after 8 hr, which mimicked the act of praying by lighting a lamp in front of god's idol. We

FIGURE 6. Prabhakar experiencing exercising with the ReExercise sketch where the feedback is in the form of LED that is placed in front of the idol of Ganesha.

asked the couple to experience the sketch, followed by a discussion of the experience.

4.4. Embodied Self-Monitoring: The Definition

During these explorations, our understanding of embodied self-monitoring became clear. In particular we realized that the rehabilitees perform the actions of self-monitoring (and performing their exercises) not in isolation but as an integral part of the social and material settings of their everyday life. Based on this understanding, we defined embodied-self-monitoring as *measuring, recording, observing, and performing other such self-monitoring actions for adhering to a prescribed treatment or therapy in concert with the physical and social settings embedding these actions.*

Embodied-self-monitoring basically calls for an "unboxing" of the tools of physical rehabilitation as they move from the structured and supervised settings of a clinic to the unsupervised settings of a home. As we discuss the notion of unboxing later in this article, it suggests a move away from the design of monolithic digital systems. Foregrounding the embodied nature of physical rehabilitation suggests a focus to facilitate rehabilitee engagement with the designed technology as a part of the everyday settings of their rehabilitation. In particular it suggests a focus on facilitating engagement with technology as one of the resources that works in concert with how the rehabilitees engage with their everyday spaces, objects, and people in order to shape their adherence.

5. REVISITING: LIVED INFORMATICS IN OUT-OF-CLINIC PHYSICAL REHABILITATION

On revisiting the explorations from the emerging perspective of lived informatics we came across a range of examples of how the rehabilitees used their personal rehabilitation data for multiple purposes, broadly toward making sense of their physical rehabilitation process. Lived informatics has emerged as a critique and response to the five-stage personal informatics model (Li et al., 2010), which has become a somewhat canonical model guiding the design and development of personal informatics systems. Recent works (e.g., Harrison, Marshall, Bianchi-Berthouze, & Bird, 2015; Yang, Shin, Newman, & Ackerman, 2015) critique the stage-based personal informatics model particularly highlighting how the model foregrounds the stages as being isolated from their context. Rooksby et al. (2014) suggested the term "lived informatics" to highlight how people use self-tracked data in multiple ways as part of their everyday life. The authors critiqued the stage-based model as being too technology centered disregarding how people actively "interweave" tracking and the tools for tracking as part of their everyday life and not in the form of clearly delineated stages. Epstein et al. (2015) built on the notion of lived informatics and proposed a model that is more reflective of the way people engage in self-tracking as part of their everyday life. Both these works propose alternative models for the design and development of personal informatics systems. However, we read these works in more general terms, as basically calling for an explicit focus on understanding and designing for the lived aspects of data.

We realized how well aligned our work was with this broader call when revisiting our explorations. What emerged, when revisiting our work with a focus on the production and use of data, was a nuanced understanding of how personal rehabilitation data take on multiple roles as part of a rehabilitees lived, everyday settings. For example, rehabilitees imagined personal rehabilitation data as a physical prop in conversation between friends and as a physical marker in a living room subtly reminding of the exercises performed. Some also enacted how recording and reading personal rehabilitation data could be an opportunity for the spouse of the rehabilitee to be involved in the activity of exercising. In this section, we elaborate on these examples, particularly focusing on reporting how the rehabilitees envisioned and enacted multiple roles of their personal rehabilitation data as part of their out-of-clinic physical rehabilitation efforts.

We present our examples of the multiple roles of personal rehabilitation data into four categories:

1. Becoming your own standard of reference
2. Marking your life as a rehabilitee
3. Articulating with therapists, partners, and peers
4. Incorporating exercising with everyday activities

5.1. Becoming Your Own Standard of Reference

The two MagicMirror explorations looked into the design of systems that would allow the rehabilitees to self-record their exercises at clinic and at home and use these videos as "mirrors" to see their progress in rehabilitation.

During both MagicMirror explorations, we observed how the participating rehabilitees envisioned and enacted multiple uses of their personal rehabilitation data to turn their bodies and the social and physical settings of their physical rehabilitation into a reference point for understanding their rehabilitation process. Next we present the specific instances across both the explorations that bring forward how the rehabilitees used their personal rehabilitation data.

Anita and Anna, the participating rehabilitees in the MagicMirror explorations, envisioned and enacted how by video-recording their own exercises they could engage with their body as an index for seeing how they have healed over time and across the different settings where they exercised. Anita and Anna decided what to record, how and where to record, and how to view and make sense of the video recordings based on the purpose of doing so. These purposes were, for example, to monitor their progress while performing the exercises and to know of the progress they make over time in managing ADL, such as picking the towel from the floor. However, both Anita and Anna enacted these possibilities in different ways.

Anita was more receptive to the idea of simultaneously viewing on her TV the reference video and the video of her current exercise while she is performing the exercise in her living room. The reference video showed her performing the exercise for the first time at the clinic. When the video of her current exercise was overlapped on this reference video, Anita got the immediate visual feedback of how much more she could stretch her hands above her head, as compared to the 1st day of her treatment (see Figure 7). She mentioned how by looking at the current video of how much she stretches her arms with reference to her original video, she could visualize the progress she made over time. Anita also imagined how, if she could go through the daily videos of the exercises, she could see for herself how she has progressed over the days.

Meanwhile, during the exploration at Anna's home, we found that she moves about her house when she performs her exercise. She performs the sit–stand exercise with the help of the dining chair and the stepping exercise on the small flight of stairs that lead from the living room to the dining room (see Figure 8). In particular, Anna did not use the stepper given to her by the rehab center, instead using the flight of stairs, as the stepper was "ugly" so she hid it in her garage. Here, guided by embodied self-monitoring we embraced the way Anna actively uses her physical settings in order to exercise and envisioned a more portable version of the video-recording and playing device, which we termed as MyReDiary (see Figure 9).

In addition, Anna felt that the overlapping of the reference video with the current video would confuse her. She said, "It will confuse me. Looking at what I did and what I am doing now … it is difficult! I would like to see what I did at the rehab center separately, maybe when I am relaxing in the afternoon." She mentioned how

FIGURE 7. Video of Anita exercising overlaid with information to give her real-time feedback.

she would prefer to look at the reference exercise video before she begins her exercises, while relaxing in the living room. She also mentioned that she would look at the videos of the exercises she performed in the home after she has performed them, in order to gauge for herself how she has made a progress.

Furthermore, during the enactment of the discussion of the home videos with the therapist at the clinic, Anna gave us a demonstration of how frustrating it is to manage even simple everyday tasks, picking up a towel from the floor for instance, when she is dealing with a new hip joint (see Figure 10).

She had brought with her the pincher to pick up the towel and other things to help articulate her everyday difficulties. She mentioned how to be able to video-record these instances, and sharing with her therapists and family will help her to talk about her everyday situations. Furthermore, she mentioned how recording a series of such videos of her doing her everyday activities, and not just about her exercises, could give her an overview of her progress that she has made in her life as a rehabilitee over time.

In summary, these instances highlight how both Anita and Anna envisioned and enacted multiple ways to use their self-recorded videos to refer to their own bodies and the settings of their out-of-clinic physical rehabilitation and make sense of their efforts.

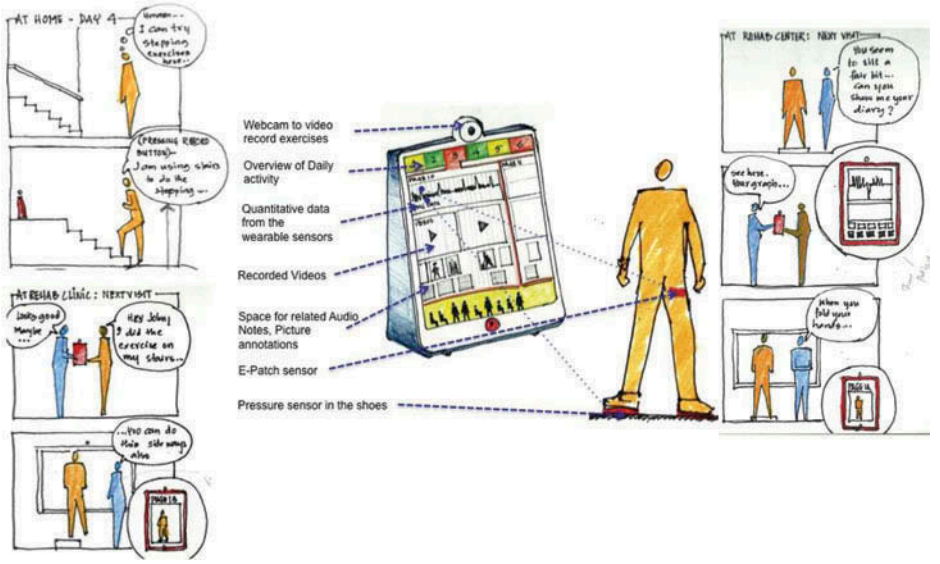
FIGURE 8. Anna exercising on the stairs with the MagicMirror interactive sketch.

5.2. Marking Your Life as a Rehabilitee

We discovered the rehabilitees enacted and envisioned different ways through which their personal rehabilitation data could become a marker or a token of their life as a rehabilitee and become a part of the physical and social settings of their physical rehabilitation. We present instances from MagicMirror, ReSwing, and ReWall explorations to elaborate on this finding.

In the MagicMirror exploration, Anna imagined how video-recording the home exercises and carrying them back to the rehabilitation center acts as a physical reminder for her to exercise at home. She said, "It is like a whip! You know, they [the rehabilitation center] send this van to pick me up to the rehabilitation center. I am tired and lazy to go sometimes, but as soon I see the van, I have to go. I guess this [video recording] will be something similar." Here, Anna imagined how she could use the activity of recording exercises as a reminder of the exercises that she has to perform. Guided by embodied self-monitoring, we embraced Anna's vision and gave a physical form to the videos by sketching the MyReDiary as a portable, dedicated, and personal video and data journal (see Figure 9). The MyReDiary tablet gave a physical form to Anna's videos and other rehabilitation data. Anna imagined how merely looking at the physical device itself, without even looking into the data, could

FIGURE 9. Paper sketch and scenarios of MyReDiary.



act as a reminder to perform her prescribed exercises and record them to take them to the clinic.

Along similar lines, Gita in the ReWall exploration imagined how she could use the colored LED on the decorative wall hanging as a subtle reminder of her daily exercises. Gita envisioned how she could see and understand the data (on how much she bent her knee on a given day) in very personal and subtle manner as the LED display was integrated with the textile and only she knew what it meant. She mentioned how for visitors, it is just a decorative part of her living room. Meanwhile, in ReSwing, Gita enacted and experienced how she could use the data presented in the form of LEDs on the trophy not as a visual reminder of her exercise but as one part of the constellation of awards adorning her living room. For her, and her husband, the trophy was just another addition to the other trophies; whereas the others displayed Gita's expertise in music, the ReSwing trophy displayed her expertise as a rehabilitee in general and specifically her ingenuity in integrating the exercises with her everyday settings.

In both the ReWall and ReSwing explorations Gita mentioned how even as she was cleaning and dusting the living room, she could see the LEDs on both the trophy and the decorative wall hanging, which could trigger her to think about her exercises and rehabilitation in general. Similarly Gita could use the trophy in her living room in an impromptu manner as a prop to discuss her life as a rehabilitee when people visit her (please refer to the next finding for a detailed discussion about this aspect).

FIGURE 10. Anna enacting the possibilities of recording data about her ADL and sharing with her therapists.

In summary, these instances highlight how the rehabilitees enacted possibilities of personal rehabilitation data as visual and material markers of their living environments that reminded them not only about their exercises but also in general about their life as people undergoing physical rehabilitation.

5.3. Articulating with Therapists, Partners, and Peers

We found how the rehabilitees enacted and experienced multiple possibilities for using personal rehabilitation data as a resource to shape and inform their conversation with their therapists and peers and other visitors. Furthermore, we also found instances of how the activity of recording and reading personal rehabilitation data became an opportunity for the spouse of the rehabilitee to be actively involved in the rehabilitation process. We draw from the MagicMirror, ReSwing, and ReExercise explorations to elaborate on this finding.

In the MagicMirror exploration we took videos of Anna's home exercises back to the clinic and staged a discussion between Anna and Rasmus, her physiotherapist. However, Anna could not articulate to Rasmus how she performed the exercises at home, and he had to encourage her by asking leading questions. This raised for us the possibility of Anna working with the recorded videos at home so that she can be prepared to share and articulate how she performed the exercises at home, what goals she can achieve, and how to

modify or set new goals with her therapist. Furthermore, Anna demonstrated how it is not only important to work with previously recorded exercise videos but also important for her to decide on what to record at home, such as her ADL of picking a towel or watering the plants so as to discuss with her physiotherapists if she is doing them in the right manner. Anna also imagined how she could share these self-recorded videos with her friends and family as a way to talk about her life as a rehabilitee.

Guided by embodied self-monitoring, we envisioned that through the MyReDiary tablet (see Figure 9) Anna could record data in the form of videos and images; annotate them with audio or text; and carry these annotated videos or images to the clinic to articulate her questions, experiences, and insights during the meeting with her therapist.

Meanwhile, in the ReSwing exploration, we observed how Gita used the awards, trophies, and other decorative objects that she makes as resources to tell her life stories (see Figure 3). We embraced this observation and speculated if and how Gita can similarly use her personal rehabilitation data as a resource to share stories about her rehabilitation process to prospective rehabilitees visiting her for advice. By displaying data about Gita's exercise on the swing in the form of LEDs on the trophy, ReSwing provides an opportunity for Gita to use the rehabilitation trophy as a prop in conversation with her friends and family. Gita mentioned how, during the deployment week, she talked about her exercises with the swing by showing the trophy to her visiting daughter.

Furthermore we encountered, quite accidentally, the possibility of how Gita could involve Kumar, her husband, as a person who reads the data about her exercise and gives real-time feedback. During our visit to Gita's home after 1 week, the couple demonstrated how they interacted with the ReSwing sketch. Gita was on the swing in the garden pushing her knees back and forth. Kumar, who was in the living room looking at the LEDs on the trophy, kept instructing Gita to increase or decrease the speed of her movements. We wondered how he came to know about the speed, as he was not able to see Gita. Kumar mentioned that he understood based on how fast the LEDs were flickering. Gita mentioned that this had been the routine for the past week, with her husband fixing the speed of her exercise based on the speed of flickering of the LEDs on the trophy. However, we had not built the sketch with this purpose! In fact, the flickering of LEDs was due to faulty coding on our part and was an accidental effect.

This accidental and surprising encounter led us to consider how closely Kumar was involved in the rehabilitation of his wife, particularly as a person who reads the data and uses them to give real-time feedback to his wife so that she can pace her exercise. During the interview postexperiencing the ReSwing sketch, Kumar pointed at the trophy and said, "Thank you for mentioning my name on the trophy. I have done a lot of work to get her on her feet. … Close friends and family knew about my efforts, but now you have given me something to make it permanent." He recounted the details about his active role in the rehabilitation of his wife, telling stories about staying in the hospital in Pune during Gita's surgery, encouraging Gita to keep exercising everyday, and modifying her exercises to suit their home environment.

In ReExercise we took on a more deliberate focus to explore the role of spouse in the rehabilitation process. We had observed how Lakshmi was always present to help Prabhakar exercise in the right manner, and her presence acted as a motivation for Prabhakar to consistently perform his exercises. We built this aspect into the ReExercise sketch (as previously detailed). While experiencing the sketch, Prabhakar laid down on the exercise mat while Lakshmi placed his elbows on the FSR. As a Hindu, Prabhakar cannot show his feet toward the idol of Ganesha, and the idol was kept behind his head. Lakshmi read the feedback from the LED and communicated it to him, "Keep this [his elbow] straight, it [LED] has to be brighter." After the exercise, we showed Prabhakar the video of the exercise he did, telling him the relation between the right posture of his elbow and the brightness of the LED on Ganesha. He smiled when Lakshmi pointed out, "See you really lit it bright." This interaction between Lakshmi and Prabhakar was close to what happened between Gita and Kumar. Here integrating religious practices with the activity of self-monitoring and exercising offered an opportunity for both Prabhakar and Lakshmi to continue the way they performed the exercises together (see Figure 11).

In summary, these instances highlight how the rehabilitees envisioned and enacted the possibilities of picking and capturing specific kind of data to share, articulating their concerns by using the data in the form of annotated video and images, and using the data in an impromptu manner as props in conversation with their therapist and peers. The rehabilitees also envisioned and enacted how the activities of recording and monitoring the data about exercises could be an opportunity for the spouse to be closely involved in the rehabilitation process.

FIGURE 11. Prabhakar and Lakshmi exercising on the bed in the living room.

5.4. Incorporating Exercising with Everyday Activities

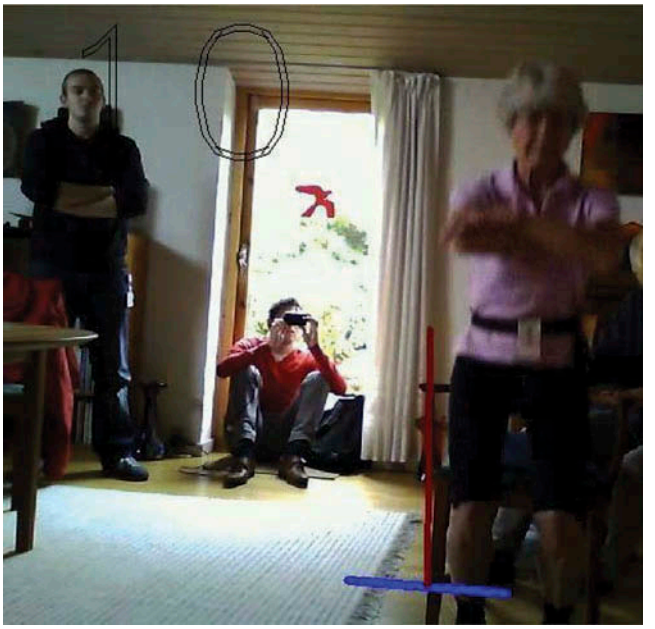
We found how the rehabilitees envisioned and enacted the different modes of using their personal rehabilitation data as a resource to turn their mundane everyday activities into opportunities for performing rehabilitation exercises. We elaborate on this finding by drawing on the MagicMirror, ReSwing, and ReExercise explorations.

During our work we came across multiple instances of rehabilitees turning their daily activities into opportunities for exercising. For example, we met a 92-year-old man who demonstrated how he exercised at home while listening to a classical music on the radio (see Figure 12). As he warmed up to the music, the hand and shoulder stretches he did as exercises no longer appeared to be exercise but turned into the hand motions of a music conductor. This instance acted as inspiration for us to explore how physiological data could become a part of and facilitate the rehabilitees in incorporating exercising into their other everyday physical activities.

During the MagicMirror exploration, Anna offered us an inspiring insight about how she had reconfigured brushing her teeth into an opportunity for performing weight balance exercises prescribed as part of her therapy. One of the electronic sketches that Anna experienced during the MagicMirror exploration was a balance-board hack with a digital counter fixed on it to count the number of steps, which was displayed on the screen (see Figure 13). After the performance, Anna mentioned that the counter reminded her of how she exercised while brushing her teeth: She performed the exercises by standing on one leg and counting to 10 before shifting to the next leg, as she brushed her teeth. Anna took advantage of the rhythm of brushing teeth—an otherwise mundane activity—in order to keep pace of her exercises. Inspired, we speculated if and how Anna's brushing-as-exercising can be

FIGURE 12. 92-year-old man exercising at home.

FIGURE 13. Anna's video that shows the count of her exercises, which prompted her to share her toothbrush story.

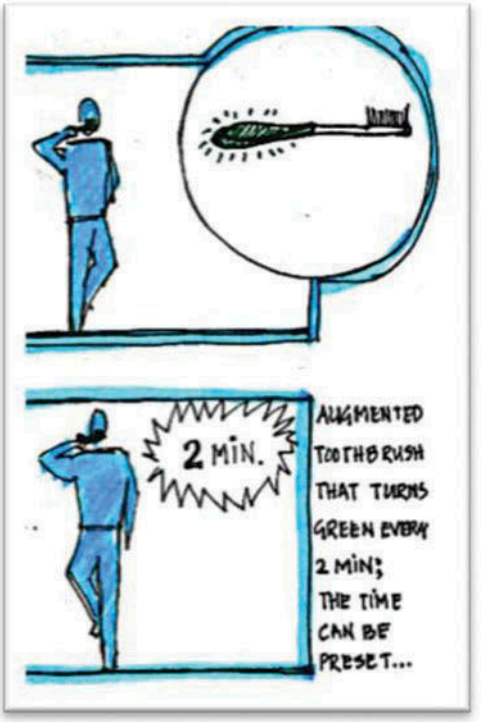


enhanced with digital technology. We envisioned ReBrush as an example of a technology that can help Anna to place simple timers or counters on her toothbrush, through which she can keep track of the exercises while brushing her teeth everyday (see Figure 14). Although Anna felt that she would not use such a brush, as she already had the hang of the timing, the sketch pointed to a greater possibility, which we utilized to further inform our exploration in ReSwing (refer to Bagalkot et al., 2012, for a detailed reflection).

We mentioned previously how Gita had already turned her swing activity into an opportunity to exercise her knees. During the ReSwing exploration, Gita took the ReSwing mat and placed it on the foot-operated sewing machine, and as she flexed her knees to operate the machine, the accelerometer recorded her knee movements and presented it on the trophy. In this sense, Gita not only used the mat to record data about one everyday activity but enacted how she could actively collect data about other activities that involved her flexing the knees, turning them into rehabilitation exercises.

Meanwhile, in the ReExercise exploration, Prabhakar and Lakshmi experienced how by exercising they could light up the LED, which when placed in front of the Ganesha idol turns the activity of exercising into praying by lighting a lamp, thereby

FIGURE 14. The rebrush paper sketch.



blurring the distinction between exercising and praying (see Figure 6). As Lakshmi mentioned just after the enactment with the sketch, "It is good [to see the feedback as a LED in front of Ganesha]. We can keep this Ganesha here in the living room and keep lighting it [the LED] up; we light the lamp in front of idols [that they keep in the prayer alcove in the kitchen] twice everyday."

In summary, these instances highlight how the rehabilitees envisioned and enacted the possibilities of instrumenting the objects—a toothbrush or a sewing machine—that they use to perform an everyday activity to gather body and physiological data while involved in the activity. The rehabilitees used this data to turn the everyday activity into an opportunity for performing the exercises prescribed as part of their rehabilitation.

6. DISCUSSION

The multifaceted roles that personal rehabilitation data take on point to how embodied self-monitoring orients the designer to foreground the situated and embodied

acts of physical rehabilitation in design for lived informatics systems in support of out-of-clinic physical rehabilitation. However, a lived informatics designer is still left with the question of how and where to begin their design. In this section we return to the earlier introduced transactional PEO model as a frame to suggest entry points into designing for lived informatics in the domain out-of-clinic physical rehabilitation. We structure our discussion into three sections. In the first section we reframe the working hypothesis of physiotherapists into an interaction design challenge. In the second section we discuss the three circles of the PEO model as entry points for design for lived informatics in support of out-of-clinic physical rehabilitation. Finally we outline the opportunities for lived informatics researchers in the domain of out-of-clinic physical rehabilitation guided by the notion of unboxing.

6.1. Reframing Physiotherapists' Working Hypothesis as an Interaction Design Challenge

Previously we discussed how the practice of physiotherapy works with a working hypothesis that the integration of physical rehabilitation exercises with mundane, everyday activities will lead to better adherence and hence, in turn, more successful out-of-clinic rehabilitation. Based on our research background and interest in the intersection of interaction design and mobile and pervasive computing, and experiences of engaging in the design explorations, we reframe the field of physiotherapy's working hypothesis as a design challenge—namely, *how to design mobile and pervasive digital technologies to help rehabilitees and rehabilitators in turning ADL and their settings into parts of a prescribed regimen for physical rehabilitation.*

To briefly review, Anna in the MagicMirror exploration and Gita in the ReSwing exploration had already turned their everyday activities of brushing teeth and enjoying the swing, respectively, into opportunities to perform their rehabilitation exercises. We explored if and how we could instrument the toothbrush and the swing to open up opportunities for Anna and Gita to engage with their personal rehabilitation data in multiple ways.

We find from our experience that ADL offer a unique opportunity for exploring the design of novel pervasive and mobile technologies in support of lived informatics within the context of out-of-clinic physical rehabilitation. In particular, we find that focusing on instrumenting how a rehabilitee performs an ADL can open up an opportunity for the rehabilitee to turn the ADL into an exercise prescribed as part of his or her therapy. This focus on designing for turning ADL into opportunities to exercise opens up a new space of design of digital technologies in support of lived informatics in out-of-clinic physical rehabilitation.

6.2. Designing for Lived Informatics for Out-of-Clinic Physical Rehabilitation: An Invitation

As described earlier, the PEO model focuses on the transactions between a person, their occupation, and the environment where this occupation happens. During our explorations we encountered multiple instances of therapists using the model to plan their interventions. Meanwhile, because of our grounding in embodied and situated interaction, we explicitly focused on observing and designing for how the rehabilitees engaged with their particular social and physical settings in order to adhere to and perform their prescribed therapy. Based on this experience, we claim that the PEO model offers entry points for design work aimed at designing lived informatics tools in support of out-of-clinic rehabilitation. We position the circles as entry points for design, but as the design work progresses a designer must embrace the relationships between the rehabilitee; their activities, tasks, and occupations; and their environment. That is, the PEO model also calls for a design methodology that is situated and collaborative, as reflected by both our work and the practice of experienced physiotherapists.

Person

A person undergoing rehabilitation seems to be an obvious starting point. A straightforward possibility is to begin thinking about how to instrument the person's body with sensors and actuators to measure, track, and give real-time feedback while the person is performing their prescribed exercises.

For example, in the MagicMirror exploration we began by instrumenting Anna's body with wearable sensors, namely, the e-patch, the accelerometer, and the pressure sensor under her feet to give her real-time feedback on the video while she performs her prescribed exercises. As per early scenario, Anna had to stand in front of a television outfitted with a web camera to be able to video-record and play back her exercises at the clinic and at her home. However, when we moved to her house we soon understood that the video recording has to work with the way Anna exercises across multiple spaces in her home. MyReDiary as a resulting design idea from the in situ collaborative exploration allows Anna to continue to use the stairs rather than the stepper as the place to perform her stepping exercise and does not restrict her to perform her exercises in front of her television.

Environment

The PEO model defines environment broadly as the cultural, socioeconomic, institutional, physical, and social considerations that form the particular and unique settings for a person's occupation. In other words, the model focuses on how an individual engages with the settings as part of performing their activities, tasks, and occupation, and in turn how the settings shape the

person's performance. Physiotherapists consider the environment as another place to intervene in rehabilitation. For example, they suggest that the rehabilitees make use of pillows and cushions as obstacles in a balance-training exercise (see Figure 15) and to use filled water bottles as weights to increase resistance in exercises. Following a similar approach in design, sensing and actuating technologies could be made part of the settings where a rehabilitee performs his or her exercises to support embodied self-monitoring of the exercises.

For example, in the ReSwing exploration we leveraged the way Gita engaged with her swing to perform her exercises, and the awards and trophies in her living room as props to narrate and share aspects of her life as a musician. The ReSwing sketch brought the two physical and social aspects of Gita together to open opportunities for Gita to engage with the swing not only to continue her exercises but also to utilize the "rehabilitation trophy" to talk about her life as a rehabilitee. In ReExercise, we continued our stance of embracing the way a rehabilitee engages with his or her environment and explored how Prabhakar could continue to engage with Lakshmi as a motivator, along with opening the possibility for engaging with exercising as a spiritual practice of praying.

Occupation

As discussed before, the PEO model discusses the concepts of activities, tasks, and occupation in relation to one another. Although tasks and occupation are broader categories and are not so easy to grasp in design, in our experience daily activities offer a more concrete starting point for design. Physiotherapists train the rehabilitees to perform ADL so that they either regain or cope with their abilities to perform ADL. The ADL, such as walking, cooking, and bathing, could be instrumented with sensing and actuating technologies to track and monitor the rehabilitee's performance of the activities and possibly share with their therapists.

To review, in MagicMirror we encountered how Anna combines brushing her teeth and performing balance exercises and sketched ReBrush. We further explored the possibility in ReSwing, with a focus on how we might instrument Gita's daily activity of exercising on the swing while listening to music with a sensing mechanism that will make the data about the time she spends on the activity available as part of her social setting. Here, it soon became apparent that what matters for Gita is not a measure of how much time she spends but a physical representation of her exercises as a part of her living room conversations. These examples may not appear to strongly represent the focus on occupation as an entry point for design. However, they do point toward how design could piggyback on the rehabilitee's ongoing efforts toward combining exercising and ADL.

FIGURE 15. Therapist asking a rehabilitee to lay the pillows on the floor as obstacles to perform balance exercises in the rehabilitee's living room.

***Note*. Even the activity of laying the pillows acts as therapy.**

6.3. Unboxing: A Direction for Design

Considering the PEO model as a generative entry point also opens up "unboxing" as a direction for the design of digital technologies in support of lived informatics in out-of-clinic physical rehabilitation. Previously we mentioned how embodied self-monitoring calls for the unboxing of the physical rehabilitation tools, prescriptions, and recipes as they are moved out of the structured and supervised settings of a clinic and into unsupervised settings of a home. The approach to unbox is also reflected in how occupational and physical therapists, informed by the PEO model, not only acknowledge but also embrace the fact that the rehabilitees will have to modify both the therapy prescriptions and tools, and their own activities and environments at home to integrate the therapy with their everyday life. For example, while exploring the interactive sketch in Anna's home, her therapist saw that Anna uses the stairs and not the stepper to exercise. Rather than ask her to use the stepper, he suggested some modification to the exercise to suit the change in the step rise between the stair and the stepper.

We call for designers to take a similar direction of unboxing while designing the digital tools. In line with the physiotherapy practice, for us, unboxing is a move away from the prevailing notion of basically boxing the tools, prescriptions, and routines of the clinic and placing these in private homes. Technologies such as advanced wearable or portable sensors, actuators, smartphones, embedded low-energy bluetooth devices, advanced personal area networks, and so on, are ready to be engaged with as enabling technologies in the process of unboxing. We require situated and collaborative explorations of how the technologies could be put forward not as a stand-alone, monolithic boxed-up system but as more open-ended resources designed to work in concert with how the rehabilitees engage with their everyday spaces, objects, and people in order to shape their lived rehabilitation. Sokoler (2004) discussed with examples more broadly how digital technology could be designed as nonmonolithic solutions presenting themselves as but one of many resources available for human action and interaction in a given situation. The interactive sketches we discuss in this article are early examples of such nonmonolithic tools (a more detailed argument is presented in Bagalkot and Sokoler, 2012).

Imagine this scenario: Anna undergoes a hip-replacement surgery and visits a therapist for postsurgical rehabilitation. The therapist has a discussion with Anna and visits her home with a suite of sensors, actuators, and displays. Together they figure out which and how the everyday objects and activities that Anna engages in can be instrumented/augmented in order to sense and display data from An na's rehabilitation process. Anna then in turn starts to engage with the data as part of her everyday life, and in collaboration with her therapist she figures out specific exercises that work for her condition and settings. This sets of a number of iterations where Anna and her therapist identify modifications to the ADL she performs, the sensor-display configuration chosen, and her environment.

Recent advances in pervasive and mobile technologies make it ever easier to explore the possibilities of designing the tools for such ad hoc, in situ reconfiguration of activities and environments. We invite the community to explore the possibilities of supporting ad hoc reconfiguration as a novel area of application. Focusing on unboxing the digital tools will first open the space for designing digital tools in support of lived informatics in out-of-clinic physical rehabilitation. Secondly, and just as importantly, it will aid the physiotherapy objectives of encouraging more inclusion and participation of the rehabilitee in shaping their own rehabilitation regime.

Having said that, we acknowledge that there will be cost and scalability challenges. However, we believe that addressing these challenges may involve a reconsideration of the role of the physiotherapists. The scenario highlights how the therapist is not merely prescribing individualized therapy but rather collaboratively designing (reconfiguring) the intervention with the individual rehabilitee over time. The focus of design then must be to enable and facilitate the therapist and rehabilitee to collaboratively reconfigure the exercises and their everyday settings.

7. CONCLUSION

In this article we revisited our work of exploring the design of digital technology in support of out-of-clinic physical rehabilitation. The physical rehabilitation domain is informed by the PEO model and guided by a working hypothesis that integration of physical rehabilitation exercises with everyday activities will lead to better adherence and, in turn, more successful out-of-clinic rehabilitation. Informed by the theory of embodied and situated interaction, and closely aligned with physiotherapeutic practice, we have been exploring the design of digital technologies in support of self-monitoring as part of out-of-clinic physical rehabilitation over the past 5 years.

We revisited this work from the emerging perspective of lived informatics and proposed multiple instances of rehabilitees using personal rehabilitation data in unique ways to make sense of their physical rehabilitation process. We described how in our work we turn the working hypothesis of physiotherapists into an interaction design challenge. This in turn pointed to opportunities for rehabilitees and rehabilitators in turning ADL and their settings into parts of a prescribed regimen for physical rehabilitation with the support of digital technologies as a resource to be integrated in emerging out-of-clinic rehabilitation practices. We presented the PEO model and suggested that it may act as a generative entry point to the design of lived informatics systems for out-of-clinic physical rehabilitation. We discussed how aligning with the PEO model also calls for adopting the notion of unboxing the digital tools—a design direction that draws our attention to the design of mobile and pervasive digital technology in support of in situ collaborative negotiation of rehabilitation regimen through ad hoc reconfiguration of activities and environments by rehabilitees and rehabilitators.

We drew on a deep understanding of the PEO model as experienced through our close work with therapists and rehabilitees in numerous interaction design research projects over the past 5 years. We present our experiences in this article as an invitation for researchers in the field of lived informatics to engage in the design of digital technologies for out-of-clinic physical rehabilitation.

NOTES

Background. This article is based on and draws from the Ph.D. thesis of the first author and from the series of design explorations that were published earlier (Bagalkot, 2012; Bagalkogt & Sokoler, 2011, 2012, 2013; Bagalkot, Sokoler, & Shaikh, 2012, Bagalkot, Nazzi & Sokoler, 2010). In this article we revisit these explorations and the theories shaping the explorations to explicitly focus on the use of personal rehabilitation data.

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