Designing to Support Prescribed Home Exercises: Understanding the Needs of Physiotherapy Patients

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ABSTRACT
Musculoskeletal disorders are a globally significant health problem affecting millions. Physiotherapy, including prescribed exercises performed independently by patients in their homes, is a key treatment for many sufferers. However, many patients fail to complete home exercises, prolonging recovery periods or accelerating decline. Pervasive health technologies, capable of monitoring users in their homes, are ideally suited to address this problem. This paper describes user research with a group of three physiotherapists and eleven current physiotherapy patients to understand the problems and user needs underlying non-compliance with home exercise regimes. The research adopted a speed dating approach and culminated with six insights and design recommendations relating to the form and type of feedback that should be used in such systems, to how scheduling and therapist-patient communication systems should be designed and to the role of privacy.

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ACM Classification Keywords
H5.m. Information interfaces and presentation: Misc.

General Terms
Design

INTRODUCTION
Musculoskeletal disorders (MSDs) are a highly significant global health problem. Many are work related; across Europe, 40 million workers, or one in seven, are affected by work-related MSDs, with an estimated total economic cost of €240 billion [33]. Time away from work is a key contributor to these costs. In the USA, 2010 figures indicate that 1.2 million injuries (each leading to a median of eight days off work) were ascribed to MSDs, representing a total of approximately 76 million lost work hours per annum [25]. Indeed the prevalence of MSDs cannot be understated; in the UK, they represent 44% of all work-related injuries [23].

However, MSDs are not only a work issue. The prevalence of such problems also increases with age, making them a pressing concern across the rapidly graying developed world [18]. For example, in the US, statistics indicate a 13% population share for senior citizens (65 or older) in 2010 with a projected proportion approaching 20% by 2030 [29]. These demographic changes will lead to a greatly increased occurrence rate of MSDs and place significant strain on existing, labor intensive treatment paradigms. These facts suggest that new techniques for the prompt diagnosis and efficient and effective treatment of MSDs will be critical to maintain current levels of care and a high quality of life in the rapidly ageing societies of the developed world [36]

Physiotherapy is a key part of current treatment methods for many MSDs. It is labor intensive, typically involving a series of consultations with practitioners who diagnose conditions and recommend exercise regimes as therapies. Treatment programs last months and involve bi-weekly (or more) clinical sessions supported by daily exercises performed independently by patients at home [e.g. 16]. Performance of exercises at home is key to achieving treatment goals. However, despite this health incentive, it has been long acknowledged that many patients fail to perform home therapies; one study reports non-compliance with prescribed exercises to be as high as 70% [32], another that 14% of physiotherapy patients fail to return for follow-up outpatient appointments [34]. The result of non-compliance is non-effective (or unnecessarily prolonged) treatments, resulting in extra costs and increased levels of pain and impairment.

This paper addresses this problem space. It explores how pervasive health systems might support patients in the

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Figure 1. bioPLUX biosignal acquisition device

performance of prescribed exercises at home. In particular, it is inspired by recent developments in bio-monitoring for physiotherapy such as the bioPLUX Clinical system (Figure 1, www.plux.info). This is a compact wireless biosignal acquisition unit capable of streaming live data in real-time to a base station. Sold as a clinical analysis service, it enables therapists to use Electromyography (EMG) to measure and display muscular activity during clinical sessions. The system's compact and robust form factor also makes the underlying technology ideal for home health monitoring, such as continuous monitoring in ambient assisted living scenarios [31].

This paper describes user research exploring how this kind of system, a muscle activity sensor, could be combined with existing connected consumer technologies, such as smartphones, to tackle the problem of non-compliance with prescribed exercises. To achieve this objective, it describes a series of interviews with physiotherapists and patients to understand non-compliance behaviors and explore how home bio-monitoring technologies might support performance of exercises at home. The paper concludes with design recommendations for this application space. The remainder of this paper is structured as follows: a review of related work in the field of physiotherapy, pervasive health and motivation; a description of the user research and concept development; conclusions and future work.

RELATED WORK

Non-compliance with prescribed physical therapy regimes often results from patients' explicit, reasoned decisions. Factors contributing to these non-compliance choices include: low perceived severity of symptoms; perceived ineffectiveness of the intervention; and unwillingness and inability to incorporate the treatment into everyday life [6]. Individual factors such as attitudes towards exercise, past experiences, availability of facilities and social environment also play a role [27, 32]. However, interventions to overcome non-compliance can be highly effective. For example, concordance, a term referring to practitioners and patients collaboratively setting treatment goals and monitoring progress can lead to substantially higher levels of treatment compliance compared to physiotherapist-mandated goals [4].

Pervasive, persuasive health technologies are ideally suited to address problems of non-compliance with prescribed exercise routines. Indeed, there is a diverse body of work demonstrating that personal digital technology can motivate and support users in performing exercises and other health related activities. Many recent systems rely on the accelerometer sensors in smartphones to count steps [e.g. 28] or GPS data to track jogging and running performance [e.g. 15]. A wide range of visualizations of this material have also been explored. For example, in Fish'n'Steps. Lin et al. [19] measured step count and tied this to the appearance, development and activity of a cartoon avatar representing the user; over a 14-week study they reported increases in participant activity levels. Buttussi [5], on the other hand, measured GPS location around an outdoor fitness trail and provided specific advice and exercise guidelines to users via a sophisticated embodied virtual trainer, or agent. One of the goals of this instructional feedback was to tackle problems of uncertainty – a common reason for avoiding exercise is concern about incorrect performance resulting in pain or aggravating problems [13].

Games and entertainment have also attracted much attention as motivational tools to support exercise performance. In many systems, physical activities are integrated into game play, such that performing exercises results in progress in the game world [e.g. 35]. A key enabler of these approaches has been the advanced sensing solutions shipping with current home entertainment consoles: the Nintendo Wii, Sony Playstation and Microsoft Xbox all come with powerful motion tracking peripherals. Using these commercial technologies, researchers have designed games to support rehabilitation from stroke [20], rehabilitation of wrist flexion and extension [10], in training individuals with cerebral palsy [11] and to support specific skills such as balance [14]. In general, exercise video games have been shown to be a valuable tool to improve overall muscular strength and bodily performance in clinical settings.

Other applications, and indeed commercial systems [e.g. 7, 30], keep track of a user's exercise performance over time, providing longitudinal visualizations of this material. The goal of this approach is to provide improved access to the results and impact of the exercise program, typically unobservable in a single session and only meaningful over a period of weeks or months [27]. Such applications are also often combined with scheduling and coordination tools. One example is the Wellness Diary [1], a mobile tool that integrates exercise planning, tracking and sharing. Studies show users struggled to enter exercise data manually but appreciated features such as reminders to exercise, rewards and achievements, recording exercise progress and automatic data analysis showing long term trends.

Researchers have also explored social approaches to motivation, such as sharing of progress to a peer group [19] or more widely via online social network services [21]. Although promising results are reported from these studies, introducing highly personal health and wellness information into the social sphere clearly also taps into issues of privacy. Perhaps unsurprisingly, some research suggests that users are reluctant to share health related information [21]. Further research is required to fully clarify these issues.

While valuable and comprehensive, this work falls broadly into two categories. It relates to either user's embarking on self-motivated and planned health and wellness activity programs [e.g. 15, 28] or relies on high end equipment better suited to clinical settings [e.g. 20]. Work at the intersection of these two spheres, in which medical professionals impact on patient activities outside the clinic is less comprehensively explored and has tended to focus on monitoring scenarios. For example, remote monitoring applications to keep track of vital signs (e.g., blood pressure [24]), or to detect non-medical emergencies (e.g., falling incidents [8]) or to report on performance of the activities of daily living (e.g., feeding [26]) have been widely discussed and the benefits of these communication channels (chiefly in terms of timely alerts and early problem diagnosis) are well established [3].

The work is this paper explores another intersection of technologies for home monitoring and clinical practice. Specifically, it examines how technology can support the performance of specific exercise routines in the home as part of a prescribed program of physiotherapy. While it is expected that many of the motivational approaches used in prior work are pertinent to this application domain, this paper argues the bio-monitor's roles as a sophisticated sensing and computational tool, as an intermediary between practitioner and patient and indeed the fundamentally therapeutic nature of the exercises themselves will impact on optimal design choices. This paper explores this space, essentially that of technology mediating the relationship between practitioner and patient, with the goal of creating systems to lower patient non-compliance with prescribed exercise regimes.

FIELD WORK

User research to achieve this objective took place in two distinct stages. In the first stage, interviews were conducted with three practicing physiotherapists. The insights captured from this process were used to generate materials (in the form of scenarios and storyboard) for a speed dating concept exploration and validation process [9] that was conducted with eleven current physiotherapy patients. These stages are described in more detail below.

Practitioner Interviews

60-90 minute interviews were conducted with three physiotherapists working in Funchal, Portugal. Their mean age was 30 and time in practice was 3-12 years. Two had direct experience (1-2 years) of using bioPLUX EMG biofeedback devices in clinical settings. The goal of these sessions was to explore issues and problems in physiotherapy treatment regimes, in particular focusing on exercise performance in home settings, on patient motivation and non-compliance, and on how biofeedback technology might add value.

The results highlighted findings from the literature. The physiotherapists emphasized the importance of both clinical treatment and also the development of a personal exercise or series of exercises to address patient needs and support rapid recovery. They reported that during initial sessions time was spent demonstrating exercises and explaining their purpose and benefits. On subsequent clinical sessions, home exercise feedback is captured from patients. The physiotherapists indicate that typical responses are that patients are too busy to perform exercises, had forgotten to do so, or that they volunteered no reason for non-completion. Although it was not possible to capture an accurate non-compliance rate in the interviews, the physiotherapists stated it was commonplace and a major frustration in their work. Underlying reasons were attributed to patients' perceived lack of immediate benefit from the exercises, lack of motivation as many patients were financially supported to attend the clinic (e.g. via socially provided healthcare) and a lack of willingness, or ability, to accommodate exercises into the routines of everyday life.

Some responses also fleshed out the literature review. One therapist reported that understanding the impact of the exercises was the most important motivator, particularly in cases where they cause discomfort or pain. He highlighted the importance of credible, understandable information and suggested that "*understanding should be achieved by making sure patients get high-quality advice about their medical condition, and that any fears are addressed by the therapist*". Another backed this up, suggesting that relatively few patients are motivated to perform exercise for enjoyment of physical activity; results are the most important driving force. They also needed to be explicit and quantified. She stated: "*just knowing that the exercise is… [beneficial] …is not good enough for the patient*" and indicated that regular subjective and objective evaluations to show progress and provide feedback are vital. Finally, several of the therapists expressed doubts about the appropriateness of social motivators. They stressed the highly individual nature of their patients and the fact that problems, progress and prognosis varied greatly – comparisons of any sort may not be meaningful. One reported: "*what is good for one patient may not be good for another. All patients are different and their problems are different too*".

CONCEPT GENERATION

Synthesizing the results of these interviews (using techniques such as affinity diagramming) with the literature on motivation and pervasive health led to the generation of six user scenarios expressing different approaches to motivating physiotherapy patients to perform exercises at home. Each was based around the core idea of EMG based bio-monitoring hardware linked to a smartphone and ultimately expressed as short storyboards. The storyboards are shown in Figure 2 and the six scenarios were as follows:

Motivation by Understanding: Home regimes can appear counter-productive to patients, particularly due to perceived ineffectiveness of exercises or discomfort [6]. This scenario explored the presentation of real time feedback illustrating the problem and effect of exercises. This was shown as live visualizations (muscles activating on a stylized body) of EMG data.

Motivation by Enjoyment: Games have been frequently explored as a mechanism to support and motivate rehabilitation activities [2]. This scenario explored the use of simple "mini-games" driven by exercise performance and interactively displayed on a smartphone.

Motivation by Results: Physiotherapy treatments work incrementally and gradually; patients experience difficulty in observing improvements in such prolonged processes [27]. This scenario explored allowing users to visualize and explore bio-sensed data charting their performance and progress over time.

Motivation by Scheduling: Willingness and ability to accommodate prescribed exercises regimes into everyday life is a key to the success of a treatment program [6]. This scenario explored the use of technology to prompt patients to complete exercise sessions (based on contextual cues such as arrival at home), to track completion (via biosignal monitoring) and to manage and mediate clinical appointments.

Motivation by Support: Bio-monitoring technology has the potential to increase levels of clinical support. This scenario explored online connections that transferred data recorded from home exercise sessions immediately to therapists who could monitor, evaluate and give feedback on performance immediately and outside of regular clinical appointments.

Motivation by Peers: Although the interviewed practitioners doubted the importance of social motivators, research has shown social factors such as peer pressure, public commitment and group membership are strong motivating influences [22]. Consequently, this scenario explored the role of sharing of biofeedback based exercise performance data with peer-patients.

Each storyboard focused on its overarching motivational theme, as listed above, but did this through the introduction of a number of specific, well-defined examples. For instance in the 'motivation by support' storyboard, multiple

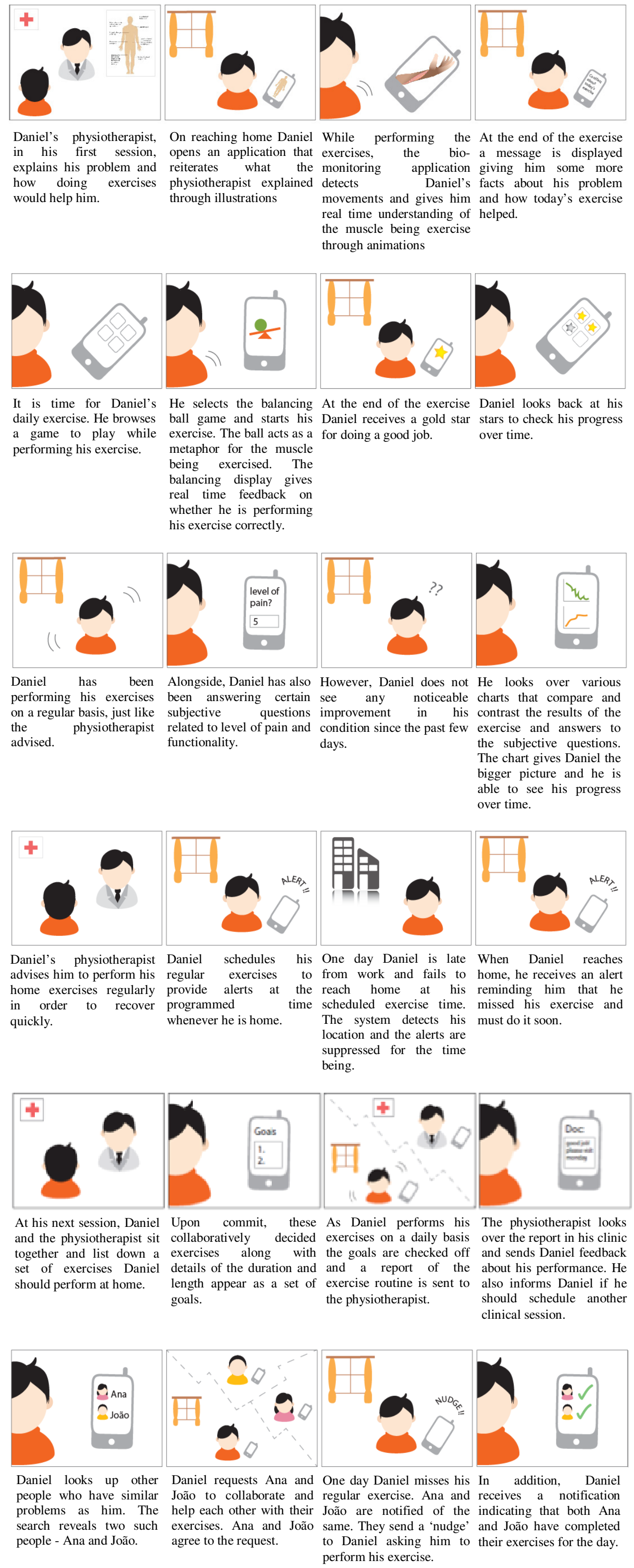

Figure 2. Storyboards used in speed boarding tests. From top to bottom, these are: Motivation by Understanding, Motivation by Entertainment, Motivation by Results, Motivation by Scheduling, Motivation by Support and Motivation by Peers.

means of practitioner support were presented, including collaborative goal setting, remote reporting of objective exercise performance and personalized feedback.

Technical and logistical details were not included in the storyboards or the discussions surrounding them. For instance in the 'motivation by understanding' storyboard, a real world patient would be required to connect a bio-monitoring device to specific muscle groups on his or her body in order to sense real time data and display feedback on a mobile device. While such issues are clearly important to any real world system design and deployment, the storyboards in the current work intentionally avoided this level of detail in order to focus on motivational factors rather than practical feasibility issues.

Concept Exploration

The six concepts were explored with the speed dating method, a rapid, low-cost technique intended to let designers and researchers quickly identify and understand the user needs and critical contextual aspects of a design space [9]. Speed Dating consists of two stages: Speed Boards and Speed Enactments. Speed Boards is a need-validation process that explores the intersection between researcher-observed and user-perceived needs. In Speed Enactments, researchers organize key factors that emerge from this process into a Speed Dating Matrix, essentially a multi-dimensional grid of possible design spaces. Concepts are generated for each cell in this grid and experience prototyping techniques are used to elicit user feedback about the full range of possible options. Speed dating was selected as a method for this stage of the research in part because of its focus on contextual factors and in part because it is suitable for exploring a wide range of ideas and possibilities in a single session. Given the complexity of systems depicted in the scenarios (involving a bio-monitoring machine linked to a mobile phone) the reliance of speed dating on structured reference material (storyboards and mocked up spaces or applications) was also valuable in ensuring sessions were grounded on relevant issues.

A total of 11 physiotherapy patients participated in this stage of the work. The youngest was of age 16, the oldest 75 and all had been in physiotherapy for at least one year. All attended the same practice and all had previous experience of EMG based biofeedback during clinical sessions. The choice of patients with prior exposure to this clinical treatment paradigm was intentional. Their experience with the technology gave them an accurate understanding of its capabilities and use. We believe this made the sessions more informative as participants had a basic understanding of the benefits provided by this treatment paradigm. The patients were in therapy for a wide range of conditions including muscle strain (due to sporting injuries), upper and lower back pain (due to overexertion), paraplegia (due to stroke or spine injury) and osteoarthritis (associated with age).

Speed Boarding Process

Eight of the participants completed a speed boarding process while the remainder completed follow-up user enactments. Speed boarding took the form of semi-structured interviews in which participants were exposed to the six storyboards. An experimenter led a discussion of each scenario in turn, eliciting opinions, comments and comparisons with the goal of extracting user needs. The discussions were 1 to 2 hours long and were centered on participant impressions of the scenario, including identifying the best and worst aspects, whether the service described would be useful or motivating and how it could be adjusted to better suit their needs. At the end of the session participants were asked to individually rate each scenario on a scale of 1-5 (1 being least appealing, 5 being most appealing) and also rank the scenarios based on order of importance to them. Such ratings and rankings were used as a tool to elicit additional user commentary rather than simply to provide explicit preference information.

In order to synthesize outcomes from these sessions, we divided the interview transcripts into individual statements and used a clustering process that bucketed each response into a set of emergent categories. Efforts were expended to ensure that statements that confirmed, negated or related to one another were appropriately sorted. Particular attention was paid to novel statements. Initially, this process identified 15 categories, but these were eventually refined to a pair of closely related overarching themes: reliance and privacy. At heart, both related to patient trust during performance of home exercises. Reliance referred to trust in the veracity of the feedback and information received in response to the exercise, whereas privacy related to the willingness and extent to which patients would share this information: to a digital system, to their therapist or to family or peer group members.

These themes were broken down into two further dimensions. Both were temporally based. The first considered interventions to support exercises that take place before, during or after exercise completion. The second related to the proactive or reactive nature of system features - whether or not the system monitors and attempts to guide and prompt a patient towards desired performance, or simply responds to events and data recorded. For example, a proactive system would remind a user to perform exercises, whereas a reactive system would inform a patient that an exercise session had been missed.

Two other dimensions also emerged strongly from the transcripts. Both related to individual differences across a range of patient *conditions* and *characteristics*. The condition dimension related to severity (in terms of symptoms and functional limitations) and prognosis of a patient's ailment. On the other hand, the characteristics dimension covered exercise history, self-efficacy, exercise beliefs, age and lifestyle. These important and complex factors were excluded from further analysis as they have

Reliance & Privacy		Pre-exercise Alerts	During exercise Correctness feedback	Post-exercise Encouragement feedback
Self	Proactive	You set alerts on the bio-monitoring device as reminders to perform exercises on time	You rely on your own judgment of right or wrong when performing exercises	You give yourself a “star” rating based on your satisfaction with today’s exercise
	Reactive	You keep track of the exercises you have missed on the bio-monitoring device	You record your pain and functionality on the bio-monitor to understand if you are performing the exercises correctly	You look up charts comparing and contrasting the results of exercise and answers to subjective questions
Device	Proactive	The device observes and keeps track of your routine; it decides when the best time for you to exercise is and sets an alert	The bio-monitor shows visualizations (metaphors for the exercise being performed) to indicate if it is being done correctly	The device awards “stars” for doing well at today’s exercises
	Reactive	The device keeps track of your routine and missed exercises; it provides a history of missed exercises	Afterwards, the bio-monitor provides a summary status that indicates whether the exercise was performed correctly or not	The bio-monitor provides feedback on how you can perform the exercise better and changes your exercise set if you are not showing improvement
Therapist	Proactive	You share your calendar with your therapist and she/he sends you an alert when you have to perform an exercise	The bio-monitor captures your exercises performance and sends it to your therapist for immediate analysis	The therapist monitors your exercise through the bio-monitor and provides you real time encouragement through supportive messages (e.g. “Good job!”, “You can do better”, “Good improvement”)
	Reactive	Your therapist keeps track of when you miss an exercise and sends you friendly reminders	The bio-monitor keeps track of the exercises and sends summary information of where you went wrong to the therapist	The therapist looks over your report and gives you feedback on correctness and performance and also recommends other exercises
Peers/ Family	Proactive	You share your calendar with a peer/family member and they send you an alert when you have to perform your exercise	The bio-monitor captures the exercise being performed and sends real time information to your peers/family	Your family member monitors your exercise through the bio-monitor and sends supportive messages (e.g. “Good job!”, “You can do better”, “Good improvement”)
	Reactive	Your peer/family member keeps track of when you miss an exercise and sends you friendly reminders	The bio-monitor keeps track of the exercises and sends summary information of where you went wrong to your peer/family	Your family member looks over your report and gives you feedback on correctness and performance and also recommends other exercises AND Your peer (also a physiotherapy patient) shares reports with you to help you compare your progress

Table 1. Speed Matrix generated for Speed Enactment process.

received considerable attention from previous authors [e.g. 6, 27, 32] Attempting to understand the relationship between them and the design space of bio-monitoring technology was considered infeasible due to the small size and diverse ailments of our participant pool.

Speed Enactments Process

After identifying these key dimensions, we created a matrix for carrying out speed enactments and future breaching experiments. This took the form of a three-dimensional grid integrating the following factors:

- **Trust level**: Reliance and Privacy were collapsed into a single dimension of trust with the following four levels: Self; Device; Therapist and; Family/Peers. It encapsulated elements of whom (or what) a patient would rely on for motivational support for exercise performance and also to whom (or what) they would be willing to share this information with.
- **Intervention Time:** This dimension referred to the time at which motivational support was provided: pre-exercise; during exercise or; post-exercise. Respectively, these temporal stages broadly corresponded to support in the form of alerts or warnings, in the form of live feedback on performance and in the form of post-exercise comments and encouragement.

- **Proactive/Reactive**: This binary dimension encapsulated the difference between prompting for and responding to events.

The cells in this matrix were then populated with fictional scenes reflecting the combination of issues described by column and row labels. A summary of this material can be seen in Table 1.

All 24 cells were explored through speed enactments using experience prototyping and future breaching experiments. Essentially, this process involved physiotherapy patients being presented with short scenarios based on each category and illustrated through simple low fidelity wireframes displayed on a mobile device. Real-time engagement with and reactions to this material were then observed. Figure 3 shows one user interacting with a mockup on a mobile device during an enactment session. Speed enactments were highly effective in revealing the attitudes patients have towards the involvement of the device, doctor and peers or family to support their motivational needs.

Figure 3. Physiotherapy patient enacts the scenario where their family member/ peer 'Ana' keeps track of missed exercises and sends a friendly reminder.

DESIGN INSIGHTS AND GUIDELINES

The results from both stages of the speed dating process were analyzed to uncover insights and design guidelines relating to the introduction of sophisticated home monitoring technologies to physiotherapist practice. A particular focus was on how bio-monitors coupled with Internet connected mobile technology (such as Smartphones) could support patient motivation and exercise regime compliance. Ultimately, six findings emerged from this synthesis process. Each is described below, both in terms of the opinions and comments upon which it is based and also in terms of its implications for design. The findings were as follows:

***Effectiveness and Correctness*:** Participants had much to say about the value and form that feedback from the device should take. Clear user needs revolved around difficulties understanding if exercises were genuinely helping to achieve therapeutic goals and whether or not exercises were being performed correctly. For example, in the "motivation by understanding" scenario, the bio-monitoring application detects a physiotherapy patient's movements and provides a real time visualization of the muscles being exercised via an animation. Users reported that this highly direct feedback would increase comprehension of the impact of their exercises, addressing problems in understanding how specific movements related to particular health outcomes.

Similarly, in the "motivation by enjoyment" scenario, users reported valuing the association between success in the game and correctly performing the physical exercises. For example, in the game depicted, balancing a ball acts as a metaphor for the muscle being exercised; when the ball is balanced, the exercise is being correctly performed. Although the game play is trivial, its simple, comprehendible depiction of correctness was highly meaningful. One participant commented: "*When I first started performing home exercises, I was very afraid of overexerting and was always stipulating my limits, so I really like the idea of knowing [in] real time [that] what I am doing is right.*" Another, commenting on both the understanding and enjoyment scenarios, said: "*The two complement each other very well. The muscle animation helps form clear understanding about the exercise and the balancing ball game gives information of right and wrong*".

In summary, physiotherapy patients struggle to relate their exercises to their conditions and worry they do not perform home activities correctly. These lacks can be addressed by bio-monitoring feedback designs that explicitly target patients' understanding of effectiveness of exercises and the correctness of their performance.

***Results are Rewards*:** Participants reported difficulties understanding their progress through long-term therapy, in which efforts and outcomes can be separated by months. They responded positively to tracking features in the "motivation by entertainment" scenario. For example, a number of participants indicated that a record of game achievements (stars awarded) would be highly beneficial. One remarked: "*Stars are the best aspect of this scenario, because the credit provides motivation.*" He later added: "*I also like the 'star' and the 'history of stars', because it indicates if [the patient] has been doing the exercise right or wrong now and in the past too.*"

But such things are not ends in themselves and their value (and credibility) lies in their correspondence with real progress towards therapeutic goals. As one patient put it, "*the rewards provide satisfaction, although a better satisfaction would be observing improvement itself*". Comments on the "motivation by results" scenario reinforced this point. In this narrative, the patient explores charts and graphs of his historical performance and subjective report (e.g. pain levels, functionality) data to gain a wider perspective on his treatment. Participants reported that such visualizations would help them gauge progress and appreciate the value and impact of home exercises. One stated: "*This is most important because it explains why the problem still exists and how exercise can help reduce the problem*".

Future applications in this space should present simple visualizations providing overviews of both short-term and long-term performance, but must ensure they accurately represent real health outcomes. At the same time, more detailed statistical data covering both subjective evaluations (e.g. self report) and objective evaluations (e.g. derived from a bio-monitor) should be available for users to explore.

***Exercise is not Entertainment*:** All participants valued the "motivation by entertainment" scenario, in which exercise is supported by a simple mini-game, for its simplicity, directness and understandable feedback. This stands in stark contrast to the widespread premise that engagement or fun is the primary motivating factor in gaming for exercise or rehabilitation scenarios [e.g. 2]. One patient stated: "*Exercises are not enjoyment even when coupled with a game*". Reinforcing this comment, another reported: "*the part that doing exercise is like playing a game, makes you feel like there is less work but it is still not enjoyment as such*". This argues against generalizing the success of commercial games with a physical component such as Dance Dance Revolution and Wii Sports [35] to the domain of prescribed home exercise performance. The data from participants in this study indicates that tying compelling entertainment experiences to exercises will have little effect on patient non-compliance rates. This is largely because patients strongly indicated they did not seek to enjoy their treatment; making and understanding progress was more important.

Games were not viewed as sufficiently motivating to encourage exercise compliance, possibly because of the widespread availability of alternative dedicated entertainment options. Instead, they were useful in that they provide clear and immediate feedback relating to exercise correctness and long term tracking of results. Future designs for gaming for physiotherapy rehabilitation should focus on accurate and informative depiction of data, not engagement or fun.

***Contextual Scheduling*:** Participants reported non-compliance behaviors due to forgetfulness and difficulty in integrating exercises with other tasks (e.g. work or school tasks). One said: "*I respect the treatment; never fail to come to the therapist, but sometimes forget to perform exercises or put [on] the ice pack. I feel like there is no time because I [re]started work right after the problem.*" Attempting to unpack these challenges, the speed enactments session explored techniques to support patients who differ in how they manage exercise scheduling, from self-reliance through to external reliance, either via a third party or fully digital service.

In response, many patients reported irritation with the idea of external parties (therapists, family members or a mobile device) mandating their routines. One indicated: "*This makes sense for young kids but not for grownups like me. I like to have control of my agenda*". In general, patients responded most positively to notions of limited context-aware autonomy: a mobile device that would remind them to perform exercises at suitable places or times of day (such as reminders to perform exercises upon arrival at home).

In sum, scheduling is a key factor in physiotherapy exercise non-compliance and future designs in this space should include for reminder and scheduling systems for exercise regime compliance that are context aware [e.g. 12].

***Lightweight Communications*:** Practitioners and patients both expressed a strong desire for improved communication relating to home exercise performance. This came across clearly in the "motivation by support" scenario, in which the patient checks off daily exercise goals in order to send a progress report to the therapist who responds with coaching feedback. Patients viewed this kind of sharing of exercise results very positively. One stated: "*It is very important to maintain communication with the therapist - the doctor has to be good for patient to get better soon"*. Underlying this opinion is appreciation for idea that care would be more personalized. Another participant suggested: "*I like the idea because it is important to give the doctor right information so that they can treat you well. The collaboration will help make a fast recovery.*" In the initial interviews, the physiotherapists were cautiously positive about this kind of collaboration. They suggested organizing one hour per day to monitor patients remotely could lead to fewer patients to deal with at the clinic, increasing productivity. On the other hand, they voiced concern about the potential for increased workload to remote monitoring commitments.

On the other hand, although patients felt communication would definitely aid recovery, they doubted that practitioners would review or respond to it. Speed enactments further highlighted complexities in this communication. In one speed enactment, patients were asked to perform their regular exercises. A bio-monitor captured the exercise and sent real-time information to the doctor for analysis. Patients liked that the physiotherapist has access to their data but did not expect the doctor to follow up. They had strong concerns about the therapist's availability and time constraints. Critical and low frequency messages were viewed as more likely to receive attention. One commented: "*I feel the message will be ignored by the doctor if it is not important. So it is more practical to send a notification to doctor only if things are wrong*".

In summary, future designs in this space should focus on enhancing communication channels between patients and therapists. But, if real-time monitoring applications are to effectively motivate users, they should emphasize the significance of the data they transmit. Communications to therapists should remain lightweight in order to be credible. Communications that do not receive responses will rapidly lose their motivational power.

***Health Information is Private Information*:** All participants viewed social motivating factors negatively.

This was explored in the "motivation by peers" scenario in which a patient requests that two others collaborate for exercise support. The three patients are notified of each other's exercise performance and can send prompts and reminders to one another. Participants responded negatively to these ideas of social feedback and sharing of their health and exercise information. Many reported appreciating how the idea would be motivating but that they would simply opt out. One derided the idea as: "*Facebook for the sick!*" The idea of sharing data with peer-patients, who were perceived to be strangers, was particularly disliked. One participant commented: "*I will not like to share personal information with strangers even though the doctor will help establish connections*." The speed enactments fleshed out reasons for these opinions. These were diverse and included: that the social aspects would lead to a lack of control; that sharing would be intrusive and impact their privacy; that the health information of others was of little interest and; a general reluctance to socialize around what they viewed as a negative aspect of their lives. Overall, participants were strongly negative about sharing even abstracted information relating to their medical condition, progress and prognosis. These results suggest that data captured by biosignal monitors is viewed as too personal for sharing with anyone except therapists.

DISCUSSION AND CONCLUSIONS

This paper highlights the problem of treatment non-compliance in physiotherapy and suggests that appropriately designed technology may be able to support patients and reduce the negative impact of this behavior. In particular it focuses on sophisticated EMG bio-monitors suitable for home use. To understand how such technologies might be able to support physiotherapy treatment routines, interviews with three practitioners and 11 patients were conducted using a speed dating approach. The resultant data was analyzed into six insights intended to guide future application and service designs in this space. The findings covered: the importance of feedback and rewards based on exercise effectiveness and correctness; the fact that patients do not seek to be entertained during their exercise sessions; the need for improved exercise scheduling systems and credible communication channels between patients and therapists and; the fact that bio-monitor based health information is viewed as too private to share. We believe these findings represent valuable guidelines that can inform future designs in this space.

A key limitation to this study lies in its sample of users. Physiotherapy patients are inherently a highly diverse group, not only because the full spectrum of individuals can suffer from such conditions, but also because the conditions themselves vary substantially in their causes, severity, duration, treatment goals and ultimate prognosis. The 11 patients in this study represented only a small sub-section of this diversity. Compounding this problem are the facts that all participants were of a single nationality (Portuguese), attended a single clinic and, barring one therapist, had prior experience with clinical EMG technology but not pervasive home health technology. While we believe the conclusions of this work to be valuable, extending it to broader and more representative user groups is a current priority. Considering a larger population will extend, refine and improve the scope and generalizability of the findings. Fieldwork that addresses the novice and/or novelty effects that may have influenced the participant group studied in this paper would be of immediate interest.

However, the main area for future work developing this research will be in the creation, implementation and field-testing of functional prototypes that support performance of prescribed home exercises. Factors such as how to combine the various features introduced in the scenarios and discussed in the insights would be an important focus – it is likely that patients would seek to use aspects that cut across how they have been framed in this paper, for instance by combining the muscle monitoring with reward systems. Furthermore, a particular topic of interest will be on customizable approaches to motivating users [17] in order to adapt to the different needs and demands of patients. Overall, this paper argues that pervasive health technologies have much to offer their users, but must be designed to match lifestyles and genuine needs. Comprehensively capturing and understanding such information will be a long and complex process and the work presented here represents a small step towards this objective.

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