Designing pervasive technology for physical activity self-management in arthritis patients

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ABSTRACT

Arthritis is a chronic condition which impairs mobility and reduces the quality of life. A physically active lifestyle is crucial for the successful management of the disease. Pervasive technology such as activity trackers can make patients more aware of their physical activity (PA), and help clinicians in getting an objective view of their patients' lifestyle. We developed a web application called FitViz which gathers data from an arthritis patient's Fitbit device and allows her clinician to use this data in setting personalized goals for the patient. We conducted a pilot study with 10 knee Osteoarthritis patients and 10 Rheumatoid Arthritis patients to test the feasibility of the application. 11 participants were interviewed to share their experiences after using FitViz for a month. The use of pervasive technology — Fitbit and FitViz — increased PA awareness, and helped in realistic goal-setting. Participants expressed different emotions — including mistrust in technology — concerning goal achievement. We use these findings to draw design implications for future pervasive technologies for arthritis patients.

CCS CONCEPTS

• **Applied computing → Consumer health**; **Health care information systems**; *Health informatics*; • **Human-centered computing →** *Information visualization*; Mobile devices;

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KEYWORDS

Behaviour change, Arthritis, Self-management, Patient–Clinician Communication, Goal-setting

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1 INTRODUCTION

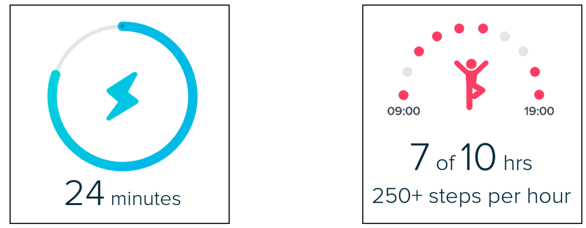
Rheumatoid Arthritis (RA) and Osteoarthritis (OA) are among the most common types of arthritis. These musculoskeletal disorders cause damage to joints, which leads to reduced functional independence and mobility, depression and anxiety [16], and reduced quality of life [14]. Self-management is a key component of the management of the disease as self-management interventions have been shown to improve health outcomes, increase self-efficacy, and reduce hospitalization [7, 20, 21]. Barlow et al. [5] define self-management as "the individual's ability to manage the symptoms, treatment, physical and psychological consequences and lifestyle changes inherent in living with a chronic condition". Self-management interventions aim at educating and training patients in skills required to manage their chronic condition.

Self-management interventions for arthritis tend to be holistic, addressing different needs of an arthritis patient such as symptoms, medication, social support, and lifestyle changes [5]. An important aspect of a lifestyle change for an arthritis patient is physical activity, which is also the focus of our work. An active lifestyle can help an arthritis patient in the successful management of her arthritis. Moderate-to-vigorous physical activity (MVPA) can reduce pain, improve mobility, and improve quality of life [23, 28, 29, 32]; the MVPA should be performed in bouts (continuous sessions of physical activity) of 10 minutes or more [15, 25]. Concurrently, inactivity can lead to reduced joint mobility and increased risk of other chronic diseases like heart disease [13]. Sedentary behaviour (sitting continuously for long periods of time), independent of the person's activity level, is detrimental to health [11, 26, 31]. Therefore, an active lifestyle should consist of bouts and non-sedentary behaviour. Despite the adverse effects of physical inactivity, adherence to an active lifestyle is weak for people with arthritis [3]. The 2011 Canadian Community Health Survey reported that 57% of arthritis patients are inactive in their leisure time [1]. Therefore, there is a need for interventions which help the patients to increase MVPA (in the form of bouts) and non-sedentary behaviour.

Existing self-management interventions rely on self-report [5] and pedometers (step counts) [22] for measuring physical activity. These measures do not measure exercise intensity (and therefore not measure bouts) and do not provide a detailed account of physical activity over a day. Fitness trackers such as Fitbit overcome these limitations by providing a detailed account of exercise intensity over a day. The detailed information can help the patients and clinicians in getting a better understanding of everyday physical activity patterns of a patient.

During our informal discussions with physiotherapists, we found that detection of bouts should take into account the physical ability of the patient. Exceeding a certain intensity or duration (as set by a clinician) during a bout can cause additional pain which hampers mobility and therefore, it is also important to determine when a patient exceeds a maximum recommended intensity and duration during a bout. The need to personalize bout detection makes the use of fitness trackers (in their current form) insufficient for arthritis patients despite the measurement of exercise intensity. For instance, Fitbit calculates active minutes by determining periods of activity which are longer than 10 minutes and are performed at a certain minimum intensity (see figure 1a). The minimum duration and the intensity for a session to be considered active cannot be changed for an arthritis patient. Furthermore, Fitbit and similar trackers are not designed to detect when a user "over-exercises".

To overcome the limitations of fitness trackers and enable patient–clinician communication based on objective measurements of physical activity, we developed FitViz, a web application which extracts sessions of moderate to vigorous activity and non-sedentary hours from Fitbit data, and allows the clinicians and patients to review this extracted information to collaboratively set a physical activity plan. The novelty of FitViz is that it enables personalization of detection of bouts and non-sedentary hours based on an arthritis patient's ability.



(a) Active minutes as seen on a Fitbit mobile app

(b) 250+ steps per hour goal in the Fitbit app

Figure 1: Active minutes and non-sedentary hour in Fitbit app are insufficient for arthritis patients

We conducted a pilot study to evaluate the usefulness and feasibility of using fitness trackers in self-management interventions for arthritis patients. At the end of the study, we interviewed patients to share their experiences. In this paper, we discuss the design of FitViz and present our findings from a qualitative analysis of the patient interviews, which we use to draw design implications for pervasive technology for self-management of arthritis.

2 RELATED WORK

Pervasive technology to promote physical activity

Pervasive technology has been used extensively — academic prototypes as well as consumer applications and devices — to promote physical activity for general well-being. For example, Lin et al. found success with Fish'n'Steps, a game where a user's step count was reflected using a virtual fish and a tank [19]. Consolvo et al. developed UbiFit Garden, which uses a garden metaphor to show user's progress towards physical activity. The system detected different activity types and performing different types of activity resulted in flowers growing in virtual garden wallpaper on the user's smartphone. There has also been a growth in the use of commercial fitness trackers. Fitness trackers such as Fitbit and Jawbone fitness tracker automatically track physical activity of their users and create visualizations to show their activity and progress towards their goals.

A common theme present in the several studies which are aimed at promoting physical activity is "awareness" [8, 10, 19]. For instance, Lin et al. found that participants who did not have an established daily exercise routine experienced an increase in awareness by playing their game [19]. Similarly, Fan et al. discovered that features which increase physical activity awareness are perceived useful by older adults; and Consolvo et al. found that the participants in their study (which investigated the use of a physical activity app) gained awareness of their current status, performance, and history. This increased awareness was found useful [8]. Existing literature suggests that features which increase awareness are perceived as useful by the users.

Self-management for arthritis patients

Clinical self-management interventions are designed to help patients in the management of their arthritis. The self-management approach is employed because it increases patient's self-efficacy and reduces hospitalization costs [7, 20, 21]. Earlier arthritis self-management interventions such as the Stanford ASMP [6, 20] had an education-only focus, where participants with arthritis were educated about the disease, medication, and skills required to manage the effects of the disease on their daily life. To assess physical activity, these interventions used questionnaires which rely on recall (for example, [24]). A limitation of using questionnaires to measure physical is that self-report measures are limited in their ability to record exercise intensity and duration.

In recent years, there is a growing interest in using pedometers for monitoring physical activity for self-management interventions [22]. The use of pedometers, in addition to the educational approach, can significantly improve the physical outcome measures in arthritis patients [30]. However, similar to self-report questionnaires, the pedometers do not record exercise intensity. In the absence of information about exercise intensity, it is difficult for the patient and her clinician to objectively measure bouts.

Existing pervasive technology is unsuitable for arthritis patients and, the self-management interventions are limited due to lack of measurement of bouts and non-sedentary behaviour. Further, the absence of physical activity data limits the collaboration with the clinicians. Although fitness trackers can measure exercise intensity at a given time, these devices do not allow customization of bout-detection and non-sedentary hours to match the user's physical ability. We developed FitViz to aid arthritis self-management interventions by allowing objective measurements of everyday bouts and non-sedentary behaviour and collaborative goal-setting.

3 SYSTEM DESIGN AND IMPLEMENTATION

We gathered requirements for the FitViz webapp via informal discussions with two physiotherapists and an arthritis patient (who is also a physiotherapist). During our discussions, we identified three key requirements for the webapp:

(1) Clinicians should be able to review physical activity information for a patient and provide a personalized physical activity plan.
(2) The webapp should extract bouts and non-sedentary hours from a patient's physical activity data, based on the patient's physical activity plan.
(3) Patients should be able to see details about their activity for a day and or a time period.

Based on the initial requirements, we developed the FitViz webapp following an iterative design process. Figure 2 shows an overview of the final application architecture. A clinician

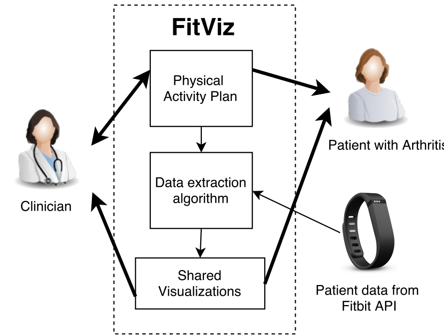


Figure 2: FitViz application design

(such as a physiotherapist) can set a personalized physical activity plan for a patient. A patient's physical activity data is collected using the Fitbit Web API [2]. FitViz uses the physical activity plan and the Fitbit data to extract bouts and non-sedentary hours. A session of continuous physical activity performed at a minimum recommended intensity, for a minimum recommended duration is considered as a bout. Any hour with the required number of minutes with more than ten steps is considered non-sedentary. FitViz visualizes the bouts, non-sedentary hours, sleep, and steps per day using a visualization for a day and calendar view which visualizes the extracted information for multiple days.

Personalized Physical Activity Plan

The patient-plan view consists of sliders — used to change the patient plan — and interactive visualizations. The plan consists of parameters which are used for detecting bouts and non-sedentary hours and goals for the total number of bout minutes and non-sedentary hours in a day. Table 1 lists the different parameters that a clinician can set using the patient-plan view. Figure 3 shows the patient plan interface, which consists of sliders to change the plan and visualizations to observe the effects of changing parameters. In our study, a patient could move sliders to see how different parameters affect their bouts and non-sedentary hour. However, we did not allow a patient — only allowed for clinicians — to save her new plan due to a risk of injury due to high goals.

Detection of activity session and non-sedentary hours

The Fitbit Web API provides FitViz with the data about the intensity of the activity (in METs), sleep, and step counts on a minute-by-minute basis; we received research access which allows access to minute-level information. FitViz uses the 'minimum activity intensity' and 'minimum activity duration' (see table 1) to detect bouts. The 'maximum activity intensity,' 'maximum activity duration,' and 'minimum interval between bouts' are used to determine if a bout is more intense than recommend, longer than recommended, and

Table 1: Definition of paramters in the patient plan

Parameter	Definition
Minimum activity duration	The minimum number of minutes required for an activity session to be considered a bout
Minimum activity intensity	The minimum intensity (in METs) to maintain during an activity session
Maximum activity duration	The maximum time allowed for a patient to perform MVPA in a session
Maximum activity intensity	The maximum allowed intensity for a bout session
Minimum interval between bouts	The minimum number of hours to take a break between two activity sessions
Non-sedentary break time	The minimum number of minutes for taking a non-sedentary break every hour
Non-sedentary hour goal	The minimum number of non-sedentary hours in a day
Continuous activity goal	The number of minutes a patient should spend perfoming MVPA

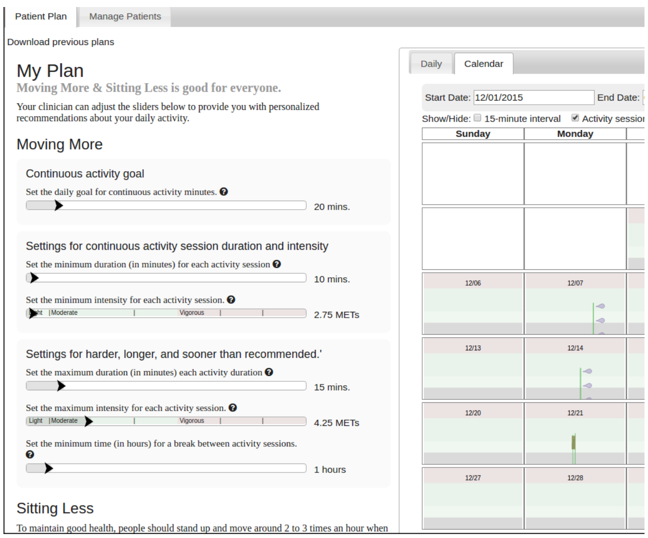


Figure 3: The patient plan view with different parameters and interactive visualizations.

performed without sufficient rest respectively. While extracting bouts, we do allow short breaks — no more than a minute with intensity lower than the minimum recommendation.

An hour with the minimum number of minutes with more than ten steps is considered non-sedentary. Recently, Fitbit also added the non-sedentary goal in their dashboard. At the time of our study, Fitbit dashboard did not include the non-sedentary hour goal (see Figure 1b). However, our implementation differs from the Fitbit non-sedentary hour goal. In FitViz, a clinician can personalize the non-sedentary hour goal whereas in Fitbit an hour is considered non-sedentary if a user performs more than 250 steps in an hour (Figure 1b).

Visualization

The extracted bouts and non-sedentary hours, along with the sleep and steps information are visualized using a daily and a calendar visualization.

The daily visualization shows bouts and non-sedentary hours on a 24-hour period. The bouts are shown as vertical green bars — width indicates the duration, and the height indicates the average intensity of a bout. When a patient exceeds any of the recommendations, additional marks are used to specify what aspect of a bout the patient exceeded; red squiggly lines indicate that the patient exceeded the maximum intensity; sweat drops indicate longer than maximum duration; a zigzag line between two bouts indicate insufficient rest period. The non-sedentary hours are indicated by showing a walking icon below the x-axis. In addition to a detailed view of a day, the daily visualization also shows progress towards daily goals — bouts, non-sedentary hours, and steps. In the visualization, we use the term 'activity session' instead of the term 'bout' as we feel that it is easier to understand for the patients. Figure 4 shows the daily visualization for a patient for a particular day. The patient has performed two bouts. The first bout is longer and more intense than recommended; the second bout is longer than recommended, and the patient did not take sufficient rest between the two bouts. The goals are shown on the right-hand side — activity session target, non-sedentary hour target, and steps goal.

The calendar visualization (Figure 5) shows the same information as the daily visualization over a calendar. It allows the patient to see any patterns that might exist in their data. In the calendar view, a patient can select a time period to see corresponding daily visualizations at the same time. Also, a patient can use the hour slider to select a range of time within the selected date period. When a patient selects a time period, all visualizations in the calendar view are filtered to only show the information for the selected time frame. With the calendar view, our goal was to allow patients to see two types of patterns in addition to an overview of all the days on the calendar. First, the calendar layout allows the patient to see how they perform on particular days (such as workdays vs weekends). Second, the hour slider allows the patient to see their activity for particular hours over multiple days, such as during and after work hours.

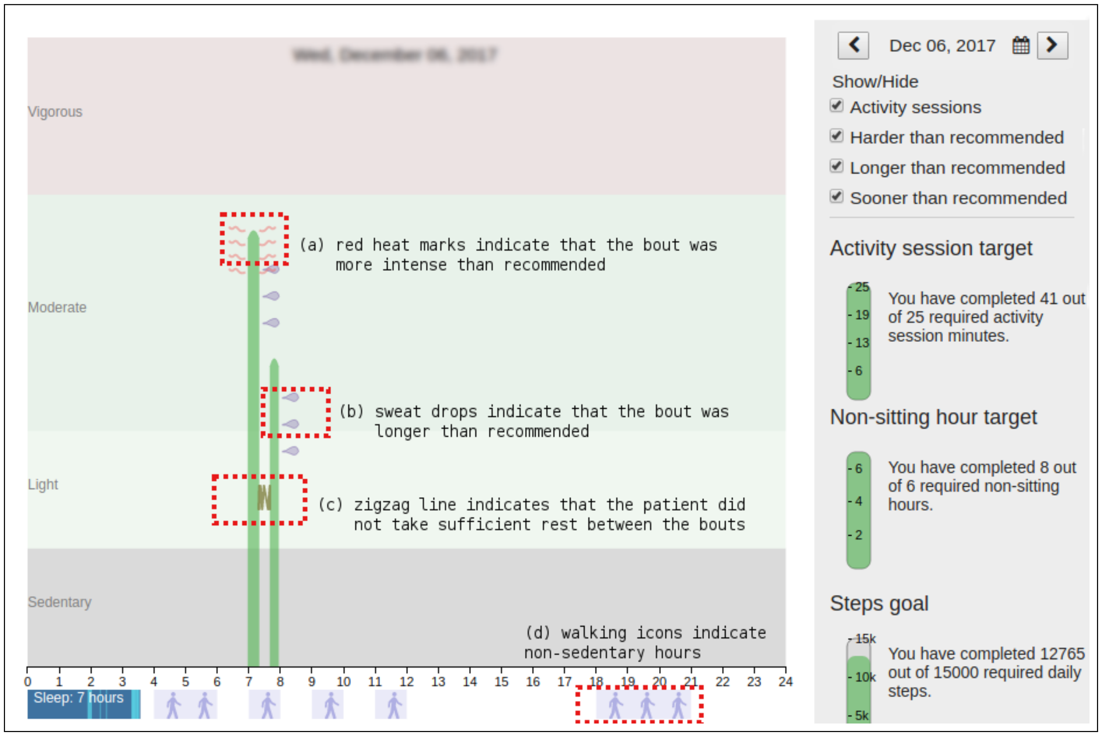


Figure 4: FitViz single day visualization to show details about bouts, non-sedentary hours, and progress towards daily goals

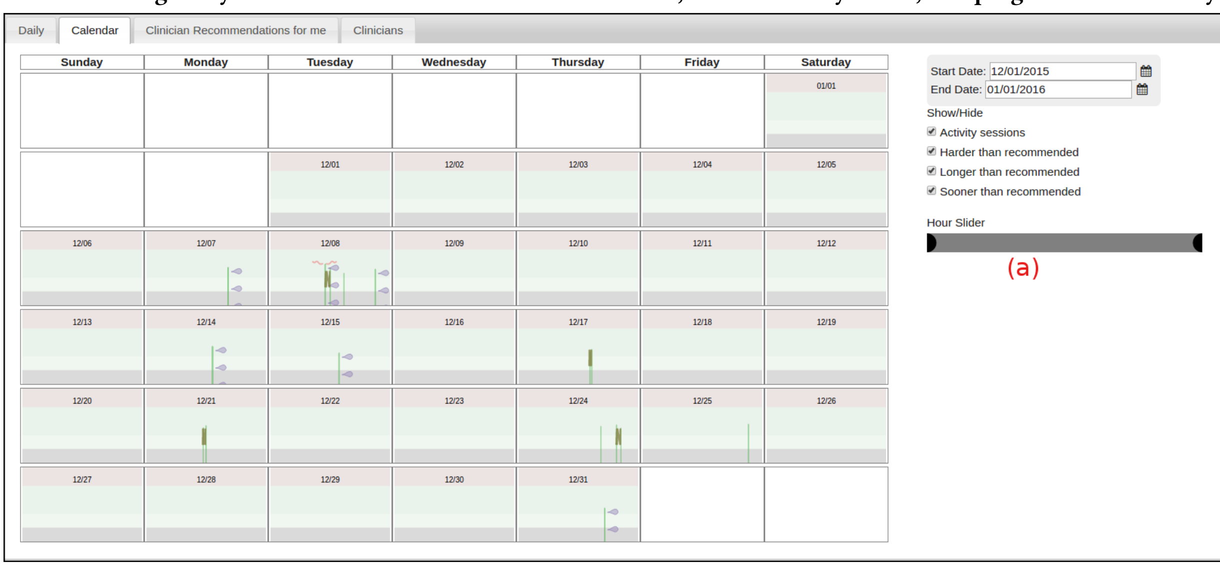


Figure 5: FitViz calendar view visualization information over a calendar. (a) the hour slider which the patient can use to control the time period for every day to be visualized

4 PILOT STUDY

Participants

To evaluate our system, we conducted a pilot study with 10 Rheumatoid Arthritis patients — 9 female, 1 male between the ages of 47 and 66, including one with both RA and lupus — and 10 patients with knee Osteoarthritis (knee OA) patients — 9 female, 1 male, ages between 64 and 69. We contacted the participants for an interview about their experience with the intervention. A total of 11 participants — 6 RA, 5 OA — gave consent for the interview. Participants were recruited from rheumatologist clinics, community physiotherapy clinics, and social media sites. The participants were included for the pilot study if they had a confirmed diagnosis of the disease, had access to a daily internet connection and an email address, and did not have any medication that may interfere with their physical activity.

Procedure

The participants attended a 1.5-hour education session, in groups of 2 to 3, where they received a standardized education from a physiotherapist. In this session, the physiotherapist addressed the benefits of physical activity, the detrimental effects of sedentary behaviour, and ways to be active without worsening the symptoms — being active without excessive exercise. The research staff helped the participants in setting their Fitbit and FitViz app. The participants used the Fitbit device, the Fitbit dashboard, and the FitViz application for one month. During this period, the participants received two bi-weekly phone calls from a study physiotherapist to discuss their physical activity and update physical activity goals, if required. At the end of the study, we requested the participants for an interview to share their experience. 11 participants responded to the request. We interviewed the participants about their experiences using a semi-structured interview. In the interview, we asked the participants to share their experience with the orientation session, using the Fitbit and FitViz app and how the two helped them, data credibility of the data collected, and their experience with the physiotherapist.

The interviews were audio-recorded and transcribed. Two researchers independently coded the transcripts using an open coding scheme. The codes were then discussed to identify recurring themes relating to the use of the pervasive technology — Fitbit and FitViz — for management of arthritis. We use **SUP-xxx** and **OPP-xxx** to quote knee OA and RA participants respectively.

5 RESULTS

Awareness

Constant and prompt awareness of self. The use of pervasive technology made the participants more aware of their physical activity behaviour — bouts and sedentary behaviour, sleep patterns, and their symptoms. The participants also appreciated that FitViz provided a detailed view of their activity.

> "*Although to me, on that dashboard [referring to the Fitbit app], that looked like I was nice and active that day except that I know that I didn't reach my daily steps but if I look at my FitViz then it actually did show my actual activity. The other thing is if you look at the Fitbit, you don't see that how many activity minutes over the course of an hour whereas if I look at the FitViz, that was really nice because the Fitbit actually showed me how many times I was actually up for that 10 minutes during that hour*" (**OPP-011**)

Although Fitbit and FitViz do not allow participants to log symptoms, the constant self-awareness made them more aware of their symptoms, and the relationship between physical activity and their symptoms.

> "*Then there was the point when I got sick and I was sleeping way more and yeah, it was just interesting to, to see that. I just found it really helpful because often we do talk about you know being restless or, or the kind of sleep we're getting and you realize oh, you know I may be going to bed and thinking that I'm getting all this sleep but I'm not actually get, doing, doing that well so and then you realize that you can adjust that as well.*" (**OPP-023**)

We observed that the use of Fitbit and FitViz facilitated two types of awareness. First, the use of pervasive technology on a daily basis kept the participants aware of their behaviour throughout the day. Second, the pervasive nature of technology facilitated a 'prompt awareness', where the participant gets aware of their physical activity and progress towards goals upon 'prompting' the technology for information. The 'constant awareness', in comparison to 'prompt awareness' did not require the participants to get immediate feedback from the device or the app. The visible presence of pervasive technology, as simple as the act of wearing a device on their wrist or looking at the visualizations on a daily basis created a constant awareness throughout the day. When visible, the technology also acted as a visual reminder to 'move more' and 'sit less.'

> "*Well, it, to me it's more of a reminder that oh, you know I've gotta move and I know full well that I have to move on a regular basis because when I don't move I can barely move when I go to stand up if I sit for any length of time. So wearing it kinda is visual.*" (**SUP-041**)

Furthermore, several participants in our study had some hypothesis about their behaviours which they were able to validate due to the use of pervasive technology.

> "*I mean I pretty much knew that I'd be restless, that I'm restless during the night sometimes and, and stuff like that. So it's not a surprise to me, but it's just kind of a, just validates what you know already.*" (**SUP-041**)

Awareness aids in strategy-formation. The increased awareness helped the participants in employing strategies to increase physical activity. Constant and prompt awareness helped the participants in forming strategies in different ways. Constant awareness enabled the participants in making changes to their behaviour. For example, OPP-005 now leaves her lunchbox in the car to increase steps during lunchtime. Prompt awareness allowed the participants to make corrective measures to reach their goals. SUP-041 would look at the information about goals before bed and walk around the house to reach their goals.

> "*I'll do things like okay, I'll park my car, I park my car out, and [inaudible], I park my car out in the parking lot and I leave my lunch in it so that when it's recess and I need to have, and I want to get my snack*" (**OPP-005**)

> "*And I'll pull it up and look and see how close I am if I haven't, and if it's relatively close, I might walk around the house a couple of times or I'll walk down the driveway a few times to see, to get it to that. It does little things like that.*" (**SUP-041**)

The increased awareness also helped the patients in spreading their bouts throughout the day. Often, it is not possible for people with arthritis to dedicate long periods to performing MVPA. Spreading out the physical activity throughout the day makes it easier to achieve goals.

> "*At, I would just look at the whole, the whole day, see how many times I had done a little bit of exercise, you know 'cause some days I, I think in the past I, I used to think that if I only had 10 minutes that maybe, that maybe I'd just wait 'til I had a longer time, which subsequently some days I didn't have much more than two or three 10 minute sessions in the day that I could, or that I felt that I was, could devote to some fitness. And that was one thing that this, being involved in, in this trial or fit, Fitbit usage, made me realize that that, it all adds up, that I don't have to do 30 minutes or 25 minutes of something*" (**OPP-023**)

Goal setting

Collaboration with Clinician enables realistic goal setting. Patients and clinicians were able to look at the same visual presentation of the activity information during the goal-setting. Shared visualizations enabled the patients and clinicians to collaborate based on objective measures of physical activity — bouts and non-sedentary hours. Without FitViz, the detection of bouts and non-sedentary hours is either absent (as in self-report measures and pedometers) or not personalized (in case of using fitness trackers only). Objective and personalized measures of physical activity lead to realistic goals — setting physical activity plan based on patient's physical ability — as the patient and clinicians do not have to rely on memory recall for measurements of physical activity.

> "*I thought that there was really good understanding and we were going through, looking at the results at the same time, so you know I felt that, that was good, there was really, it wasn't like I had to explain things really well because it, she could see the visual herself*" (**OPP-005**)

OPP-005 further added, "*I think that the physios really help you to um, uh make really realistic goalsetting*".

Personalized goal-setting. The technology did not require the participants to perform specific exercises. The goal was to allow participants to incorporate MVPA in their existing activities. Participants liked that the goal-setting in FitViz allowed them to continue their everyday activities, monitor them, and make changes to reach goals. Participants appreciated that they were not required to incorporate new activities into their life.

> "*he [the physiotherapist] was, was giving me some directive as to what I should be doing, but it was most certainly left up to me to tailor it to my, what I thought that I could do based on what kind of activities I had been doing in the past. And, and so for me that was good.*" (**OPP-023**)

Goal Achievement

The patients expressed different attitudes when discussing about achieving goals. While achieving goals is motivating for the patients, not-achieving them can induce feelings of guilt and distrust in technology.

Distrust in Technology. It was extremely frustrating not to be rewarded with progress towards a bout after spending considerable time performing MVPA. Some participants did not see a bout — when expecting to see one — because of the strict nature of our bout-detection algorithm. The algorithm does not allow a wiggle room for bout identification. A session of activity will not be considered a 'bout' if there was a low-intensity break for more than a minute or the average intensity level was even slightly lower than the recommended value. The visualization and the algorithm either identified a bout or showed no progress at all (other than perhaps non-sedentary behaviour for an hour). This causes a sense of frustration, which leads the user to distrust technology [12].

> "*and it was intensely frustrating for me at first you know because I'd think god, I was like working so hard and it didn't even show up. And I was thinking what is going on here? So that was very frustrating.*" (**SUP-047**)

> "*the one thing that I found annoying was because I live in an urban area and when I go out for a walk, I have stoplights. And when I first went out, I like I was frustrated and I didn't want to be, I*

> *ended up having to be one of those people okay go ahead, press the button to my daughter and then I walk around to keep my [inaudible] that I had 10 minutes straight*" (**OPP-022**)

OPP-022 further added,

> "*if you're, you're doing your walk and you stop at the light, you have to let people, you've gotta be like those joggers that are jogging at the light, you know keep moving, and that's, that's what you need to know, that that would be something to put in there*" (**OPP-022**)

Rewards versus Guilt. Goal achievement was also associated with feelings of guilt and reward. The participants expressed feeling happy when they looked at the dashboard and found that they have achieved their goals.

> "*I didn't really think it would make much difference to me but when you look at them, you think that's good, I did do what I was supposed to do, I fit that into my busy schedule and, and I feel better for it*" (**OPP-023**)

However, not achieving goals can cause guilt, especially when those goals were set collaboratively. The participants felt an added responsibility to meet their goals due to the involvement of a clinician. When they did not achieve their goals, it caused a feeling of guilt.

> "*I felt guilty if I didn't you know get, get to my goal, and I know, you know that's not probably the, but the awareness I think is, is really good because then you, you know, you know that you can, I mean you can do better when you know what you're doing so that works*" (**SUP-002**)

Goals become unrealistic when symptoms flare. Although collaboration with a physiotherapist fostered realistic goals, flare in symptoms can make the same goals unrealistic. Flare in symptoms is important to consider because not achieving goals can make a patient feel confused or disappointed, which can lead to lack of engagement.

> "*I thought it [FitViz] wasn't working at the beginning because we had my goals way too high [because of the flare]. Way, way too high. They would have been okay except that my meds stopped working. And I went into a horrible flare and I still thought that I was getting up every hour. I couldn't understand, like if you looked at my FitViz at the very beginning as opposed to you know a few, like this day here [pointing to a particular day in FitViz], there were some days when I barely was moving, I probably was moving at the pace of a snail ...*" (**OPP-011**)

6 DESIGN IMPLICATIONS

Support awareness through pervasive technology

Pervasive health technology should be designed to support prompt and constant awareness. The prompt awareness allows patients to take corrective steps to reach goals and the constant awareness allows the patients to make lifestyle changes. In FitViz, the visualizing everyday bouts and non-sedentary behaviour as detailed visualizations — as opposed to visualizing aggregate values for the whole day — allowed the patients to better understand their behaviour, such as the awareness about how much time in a day they spent being sedentary.

In addition to information about self, subtle approaches to awareness should also be considered. For example, mobile displays[9] and little stickers on a mobile phone [17] have been shown to increase awareness. Similar to previous work, the participants in our study reported that the device on the wrist acted as a visual reminder, keeping them constantly aware.

Provide secondary goals to prevent guilt

Failure to meet goals can cause guilt. Meeting the goal of bout-minutes every day was challenging and inability to meet these goals caused guilt. Secondary (and easier to achieve) goals can encourage patients and reduce guilt. Although not an original intention of the FitViz app, we found that non-sedentary hours acted as secondary goals. Even when the patients did not see a green bar, either due to strict nature of the algorithm or due to a flare in arthritis symptoms, the walking icons proved to be an avenue of encouragement in the absence of green bars.

Future systems will benefit by including secondary goals. Such goals keep the patients encouraged and engaged. Designers and researchers should take into account the guilt that goals can create, especially in patients who are likely already experiencing anxiety and depression. Designers and HCI researchers should investigate how secondary goals can be used to boost confidence and self-efficacy, which can increase performance for primary goals[4]. Further, designs should be carefully considered to ensure that they do not cause patients to feel guilty.

Relax goals when symptoms flare

Arthritis patients often experience a flare in their symptoms which decrease their mobility. Decreased mobility hampers the ability to meet goals. Existing consumer technologies such as Fitbit are designed for healthy individuals. However, for arthritis patients, failure to meet goals can make them feel disappointed. Therefore, pervasive health technology should design goals which change based on the current state of a patient's disease. One approach can be to create two sets of physical activity plan, one to be used as a default and another physical activity plan to be used when symptoms flare. A patient can manually change the plan to activate, or it can be automatically changed based on pain scores.

Visualize partial progress to prevent frustration

Existing systems such as Fitbit or the UbiFit Garden[9] constantly show progress towards a goal. The goal visualizations in FitViz also visualized progress. However, partial progress was not visualized for bouts. The activity session detection algorithm did not acknowledge partial progress. The algorithm made a binary choice: either the patient performed an activity session or not. Ignoring partial efforts not only causes frustration and discouragement, it can also result in pervasive technology losing credibility. Since bouts are a combination of activity intensity and duration, it is not straightforward to determine partial progress. Further research is need to explore how partial progress can be determined for bouts.

Designers should take into account how partial progress for different measures of physical activity can be determined. Similarly, visualizations should be designed to acknowledge progress towards the goals.

Support custom goals and hypothesis validation

The participants in our study expressed a desire to track custom activities — such as tai-chi and yoga — and how these affected their disease activity, often to verify existing hypotheses. Pervasive technology such as Fitbit, including FitViz, have a predefined list of goals. Further, these tools do not allow any opportunity to compare how different goals and activities affect disease and symptoms. Pervasive technology designers should take into account the different goals that their users might have and explore how existing technologies can be modified to support custom goals.

7 LIMITATIONS

One of the limitations of this study is that FitViz was not available to the patients as a mobile app. A mobile app is more appropriate for prompt awareness. Due to this limitation, it is not clear how the patients would have used information about bouts to take corrective steps during the day. Second, it generally takes a long time for a person to change their behaviour. Long-term studies are required to understand if an intervention caused behaviour change [18]. Our study duration was only one month, which might not be suitable for observing behaviour change. Although we did observe a non-significant increase in MVPA and step counts [27], a long-term study is required to know if FitViz and Fitbit can help in changing behaviour. Finally, our study was limited to RA and knee OA patients, who are required to increase ambulatory behaviour. It is not clear how technology for other types of arthritis, such as wrist arthritis, should be designed.

8 CONCLUSION

We used pervasive technology to support the physical activity self-management in arthritis patients. We developed a web app, FitViz, to measure bouts using a commercial fitness tracker. FitViz was developed to complement the Fitbit app. The participants in our study found the additional information — bouts and non-sedentary hours — useful. In addition to the self-monitoring of physical activity, shared visualizations allowed collaboration between patients and clinicians during the goal-setting phase.

Our findings suggest that pervasive technology can support the arthritis patients by increasing awareness about physical activity. Participants expressed a desire to add custom goals and understanding how different aspects of their lifestyle affect their symptoms. Further research is needed to find the best approach to integrating custom goals and empowering patients to find relationships between different aspects of their life. Failure to acknowledge partial progress can cause patients to feel frustrated, disappointed, and guilty. Designers should pay special attention to the different sources of these negative emotions and design technology which encourages patients and minimizes negative emotions associated with failure to meet goals. Finally, the designers should take into account the changing nature of the disease when developing a pervasive technology.

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