MyFootCare: A Mobile Self-tracking Tool to Promote Self-care Amongst People with Diabetic Foot Ulcers

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ABSTRACT

We present the design of MyFootCare, a mobile app to support people with diabetic foot ulcers in their self-care. Self-care is a critical component of care for people with a diabetic foot ulcer as most of their ulcer care is provided away from the clinic. To promote better self-care, we designed a mobile application 'MyFootCare' that harnesses visual analytics and self-report to provide feedback about the healing process. MyFootCare encourages people to take a photo of their ulcer with their mobile phone each time they change their wound dressing. Based on computer vision techniques, users receive graphical feedback on changes in ulcer size over time to objectively track the healing progress. Additionally, MyFootCare seeks to foster self-care through personal goals, diaries, and reminders to enact care. Feedback from three people with chronic ulcers shows that the app builds on existing practices of taking wound photos and that it is seen as useful to track progress and to facilitate dialogue with clinicians. More work is underway to evaluate the use of MyFootCare in a deeper field study.

CCS CONCEPTS

• **Human-centered computing** → Ubiquitous and mobile computing;

KEYWORDS

Self-monitoring, Personal Informatics, Diabetic Foot Ulcer, Mobile Devices[1]

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1 INTRODUCTION

There is a growing interest in HCI in self-tracking to support positive health outcomes. Several studies explored how people collect, reflect, and act on step data from wearable fitness trackers (e.g., Fitbit, Garmin), showing that people derive useful information and motivation from these data [5, 13]. Many fitness trackers also provide insights into how long and deep we sleep, which can help individuals to make adjustments to their environment and lifestyle factors that may impact their sleep [15, 19].

More recently, HCI researchers have started to explore self-tracking in clinical contexts where patients and healthcare professionals collaboratively examine the data. For example, Mentis et al., [16] examined collaboration between patients with Parkinson's disease and their clinicians around physical activity data from Fitbit devices. Ploderer et al., [17] explored opportunities for stroke survivors and their therapists based on upper limb movement data. Finally, Smith et al. [22] explored how people with diabetes and their doctors discuss diet and glucose levels tracked in daily life.

This research builds on the growing body of self-tracking technologies in medical settings. In particular, our aim is to develop self-tracking technologies that support people with diabetes in the care of their diabetic foot ulcer (DFU). DFUs are a significant complication of diabetes mellitus and without good quality care lead to lower-extremity amputation. The most frequent underlying cause is loss of sensation from diabetes in combination with unchecked foot trauma [7]. Many people with diabetes are already familiar with self-tracking, for example via diet monitoring, to proactively manage their diabetes outcomes [22]. This work seeks to build on and support existing practices to encourage self-management of wound-care.

In this paper, we present the design and early evaluation of 'MyFootCare', a self-tracking app to encourage self-care amongst people with DFU. The design has been inspired by theories of behaviour change [4], which suggest that people need the ability, motivation, and triggers to enact a desirable behaviour. Early pilot feedback from three people with a DFU shows that users consider MyFootCare easy to use. They have an existing interest in using wound photos, appreciate seeing healing progress, and they want to share results with clinicians.

2 CHALLENGES OF SELF-CARE IN DFU

Each day in Australia 50,000 people suffer with a DFU, 1,000 are hospitalised, 12 have an amputation, and four die because of a DFU; at an estimated annual cost of $1 billion [11-13]. DFUs take a toll on the physical and mental quality of life of patients, partners, family, workplaces and their communities [11]. Queensland has implemented best practice clinical care to patients with DFU and demonstrated 40% reductions in

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hospitalisation and amputation rates across the state [12]. However, to achieve further reductions in the large DFU burden, experts suggest new strategies that engage patients in self-care [1].

There are seven key elements [20], that support DFU clinical treatment: "1. relief of pressure and protection of the ulcer; 2. restoration of skin perfusion; 3. treatment of infection; 4. metabolic control and treatment of co-morbidity; 5. local wound care; 6. education for patient and relatives; and 7. prevention of recurrence."

All these elements are only fully optimized with patient engagement in self-care practices. Thus, engaging patients away from clinics remains a global challenge [20]. To date, providing patients with education and treatment information has not improved DFU healing outcomes [3]. Experts instead suggest simpler actionable tasks need to be provided for the user to support self-care [18].

DFU treatment experts have recommended using pictures wherever possible as a motivational tool and catalyst for improved communication [18]. Most recently, however, van Netten et al. [23] reported that digital images alone were not valid or reliable for monitoring DFU outcomes and recommended the need to augment digital images with thermal images, self-reported symptom diaries and computerised machine learning algorithms. However, none of this previous work has, to our knowledge, integrated motivational self-tracking, data visualisation, image capture and image processing to provide multi-faceted support for DFU self-care.

3 THEORIES GUIDING THE DESIGN OF MYFOOTCARE

This project aims to empower people with DFU in their self-care through a novel mobile application called 'MyFootCare'. MyFootCare promotes self-care through a focus on personal goals, reminders to enact care and novel visual analytics, including digital images and self-reported symptoms, to allow patients and their clinicians to track their healing progress.

From self-tracking theory, we derive key components to drive the user requirements to meet motivational theory variables. We observe from [14, 4] the need to support people in collecting information for self-reflection, motivation and future action. The major focus is to provide mobile software technology that supports this process, especially the collection phase. We note that the acquisition of DFU care skills are considered out of scope for this research and we instead focus on objective data gathering and motivation.

From Fogg's behaviour model [4] (see Fig. 1) we see that successful behaviour change is derived from two variables, viz. ability and motivation. That is, easy to do tasks do not require much motivation, compared to harder tasks. Enhancing ability (making tasks easy to do) and motivation (providing useful feedback) along with judicious use of triggers, should support the user in transition to a successful set of self-care behaviours.

Using Fogg's model, we enumerate the phases required to produce behaviour change in DFU self-care:

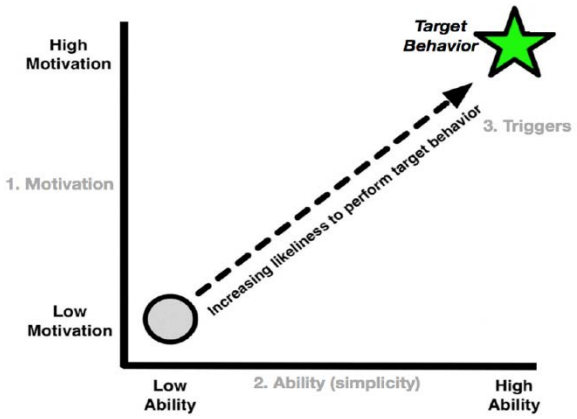

Figure 1: Fogg's behaviour model for persuasive technology [4].

1. *Trigger* - prompt the user to action on a regular basis towards success. MyFootcare provides regular reminders to write in the application diary.
2. *Motivation* - ensure compliance with helpful objective actions via motivational feedback. 'Live' objective wound tracking is used to support user motivation by visualising to the user their progress in healing the wound.
3. *Ability* - promote adherence by provision of intuitive software systems to support ease of use. A foot image capture mechanism has been developed that supports easier image capture.
4. Using the above elements, we have derived application functionality to encourage self-collection of relevant treatment care data to improve DFU self-care outcomes.

4 MYFOOTCARE PROTOTYPE

Overall the aim is to provide a diary-based approach to enhance patient-clinician communication with self-tracking data. Another aim is to provide visual analytics technology to monitor progress in wound healing: MyFootCare applies computer vision techniques to extract information from digital colour images taken through the app, when the user changes their wound dressing.

A prototype application was developed for Android devices using Java frameworks and OpenCV (www.opencv.org) for wound segmentation and analysis. Our prototype was developed on a Samsung Galaxy S4 mobile phone.

From engagement with podiatrists and previously described persuasive technology theory models, the following features have been placed into MyFootcare. A mapping to the motivation model factor and example figure reference is included in parentheses:

1. *Goal Setting* Picture (Motivation, Figure 2.a) – the home screen shows an image captured by the user to visualise the goal they wish to achieve when fully fit (e.g. an image of forest shows a place they wish to walk when healthy).

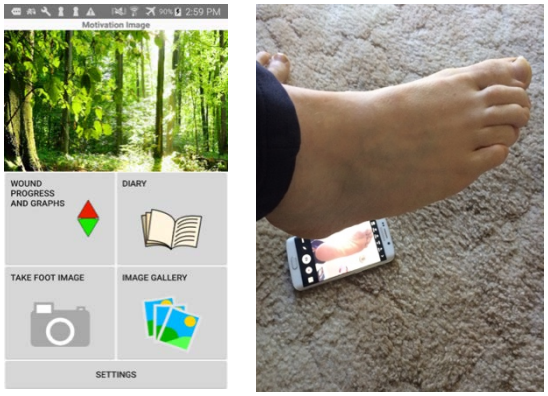

Figure 2: (a) Goal Setting Picture (App Feature 1.) on the home screen to visualise what the user wants to achieve; (b) Image Capture with voice feedback (App Feature 2.) to centre the foot over the camera.

2. *Image* Capture (Ability, Figure 2.b) – it is difficult to take photos of the foot without assistance from another person. Hence, we devised a mechanism to allow individuals to capture foot images by placing the phone on the floor and hovering the foot over it. The app guides the user through voice feedback (based on OpenCV image analysis) to centre the foot over the camera at an appropriate distance, and to take a photo.
3. Wound *Analysis* (Ability, Figure 3.) - an easy to use wound analysis method was implemented using OpenCV that automatically captures the size of the wound after segmentation from the image by drawing inside and outside the affected area.
4. *Diary* Reminders (Trigger, Figure 4.a) - daily reminders to prompt users to record daily actions and mood levels.

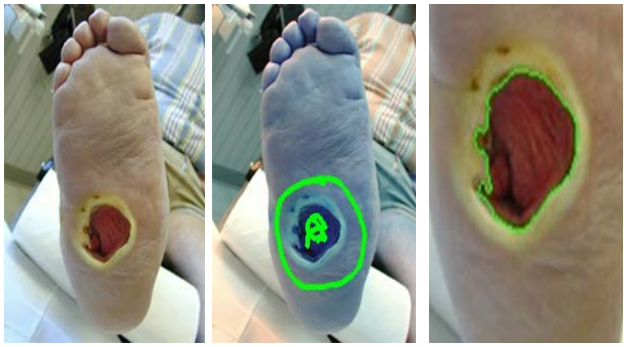

Figure 3: Wound Analysis process - take image (left), outline inside and outside of wound (middle), segmentation for wound size estimation (right).

5. *Wound Size Tracking* (Motivation, Figure 4.b) - live wound size graph visualizations, derived from segmented wound photos in Feature 2., providing reports for self-tracking and clinician communication.

5 MYFOOTCARE EVALUATION

We conducted a pilot qualitative study with three people with a DFU to evaluate MyFootCare and improve its utility. The evaluation occurred in parallel with the software development based on a high-fidelity prototype of the application, which allowed participants to click through screen mock-ups of all previously mentioned features. While not implemented, image capture concepts were presented for evaluation by the particpants, giving insight into possible future implementations.

The aims of this evaluation were to (1) obtain feedback from people with a DFU to see if the application has the potential to engage them in the care of their ulcer, and (2) to gain feedback on the utility of the application, to improve its design and functionality.

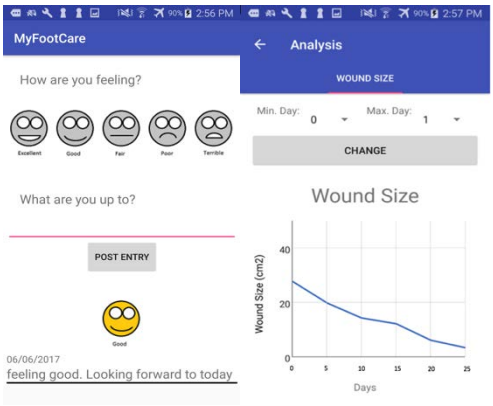

Figure 4: (a) Diary Reminders (left) - showing emotional mood and text entry (App Feature 4.) initiated by reminders. (b) Wound Size Tracking (right) - showing values drawn from wound analysis as a graph (App Feature 5.).

We recruited three people with a DFU who received foot therapy at the Chermside Diabetic Foot Service (Metro North Hospital and Health Service, Brisbane, Australia). All participants were male and 44, 56, and 77 years old. All three participants had type 2 diabetes and foot ulcers for extended periods: participant 1 had recurrent ulcers over the last 13 years (and 6 toes amputated as a result), participant 2 had one ulcer for 12 months, and participant 3 had two recurrent ulcers for 4 years. Participant 1 cared for the ulcer himself, participants 2 and 3 had spouses who enacted the wound care with them. All three participants had smartphones and received weekly clinical care from the diabetic foot clinic.

Participants were interviewed by author Si Da Seng at Chermside Community Health Centre (Metro North Hospital and Health Service, Brisbane, Australia). Standardised background questions were asked about their ulcer history, clinical care and self-care, and what applications they used on their smartphone, followed by a discussion of the MyFootCare prototype using a talk-aloud protocol. In discussing the prototype, we asked about their first impressions, followed by questions about if and how they could integrate the various features into their care practices, closing with suggestions for improving the app for their personal circumstances and needs. Example questions included, "What do you think about each individual feature?", "You mentioned that you would consider trying out this smartphone application. Why is that?" Interviews

lasted between 20 and 30 minutes. We transcribed all interviews and analysed them thematically through several rounds of reading and coding [2].

We acknowledge that the findings here are limited by the small number of participants in this pilot study and the discussion of potential use and utility, rather than actual use while caring for their DFU at home. Despite these limitations, however, the evaluation served our aims of understanding and enhancing the utility of MyFootCare.

5.1 Potential to Support Care

Overall, participants 1 and 3 were very positive about the MyFootCare prototype and saw its potential to support their care. Participant 3 indicated that the app has potential to empower him in his interactions with podiatrists: *"it would make me more involved, because that's the stuff that you guys [podiatrists] do. That would make me feel like I'm more involved and my thoughts and opinions are more valued because I'm typing in my diary how I feel."* Participant 2, on the other hand, stated *"I'm too old for that"* and elaborated that he rarely uses apps because he finds it hard to touch and type on a phone: *"I can take photos, but it would take me forever to type."*

All three participants found photos of their ulcers important to support their self-care. In fact, all three participants had taken photos of their own ulcer in the past with their own phone. Participant 1 stated *"it's a record, a memory"* and similarly participant 3 elaborated that *"no one wants to see a photo of a chronic ulcer, but for me it shows where I've come from, what it looked like then, and what it looks like now."* Even participant 2, who rarely used applications on his phone, had ulcer photos taken by his wife.

Wound size tracking graphs were seen as an easy and objective way to monitor progress. Participant 2 stated that graphs are *"simple to read; you can see if it's going down – just like what I have on my glucose monitor."* Participant 1 highlighted that graphs present information in an objective manner: *"it's not gonna lie. is it [the wound] bigger? Yes or no?"* Participant 3 pointed out the opportunity for sharing this information with healthcare professionals: *"I like that because then I can show my doctor that this is the progress that is happening. It's a nice and easy way to look at it."*

Goal setting via motivational images received mixed feedback. Participant 1 found the goal setting useful, because *"it shows what you want to achieve, like being able to shower [without a covered wound dressing]."* Participants 2 and 3 misunderstood this feature. They thought that the images would come from the app, and they missed the point that the app encourages them to upload photos that represent their own personal goals. Participant 2 said that this is *"not useful for me"*, whereas participant 3 stated that he would prefer text rather than pictures *"I prefer something like 'don't beat yourself up – next week will be better' – you see it on Facebook all the time."*

Similarly, the diary received mixed feedback. Participant 1 said that he is *"not a journal person, that's why I like the graph."* Participant 2 pointed out that he finds it very difficult to type on a smartphone. Participant 3, on the other hand, found the diary useful to add personal information to the photo and graph to *"check the fact."*

5.1 Enhancing the Utility of MyFootCare

All participants found the MyFootCare prototype easy to use. However, they pointed out several minor usability issues to improve its utility. First, the goal setting feature needs to highlight that users are encouraged to set their own goals by uploading their own photos. Second, the diary and photo section should not only capture the date but also the time of the day. As pointed out by participant 1, the time of the day provides important contextual information, e.g., *"you might get out of bed and feel excellent."* Finally, taking photos of the underside of the foot was not tested in our evaluation. We talked through the proposed process of laying the phone on the floor and positioning the foot over it, but as pointed out by participant 1, *"you'd have to use it to know."*

Participant 3 suggested adding a feature to contact a health professional for advice based on the photos and graphs. He recommended *"a section, like a messenger, where you get online help if you've got a question; for example, 'I noticed a different colour ooze coming out of the wound.' You can share the photo and ask, 'should I contact my podiatrist or can it wait to the next appointment?'"*

6 CONCLUSIONS

The main contribution of this paper is a prototype self-care mobile application with novel image capture interaction techniques, wound analysis, diary features with reminders, integrated together into a self-care service.

Feedback from people with chronic DFUs showed that the application has the potential to support care. It builds on existing practices of tracking diet [22] as well as taking photos of DFUs. The self-tracking idea was perceived well, as it *makes* progress objective and visible, and is thus a value add to their present practices. We also acknowledge mixed results on diary and goal photos; indicating the need to clarify the results through an actual trial study where people with DFUs can try out the app over several weeks.

The photo-taking process where users place the phone on the floor and receive audio feedback also needs further evaluation. Not all people with chronic DFUs have partners who support wound care and who can take photos of ulcers. Hence this feature will be crucial to allow individuals to take photos of the underside of their foot. This feature constitutes an interesting interaction design challenge, which can add to the emerging area of foot-based interaction techniques [24].

The findings indicate that the application can empower individuals with a DFU in their interactions with clinicians. Currently only clinicians (such as podiatrists) track wound size during consultation, whereas the application provides users with the opportunity to monitor in daily life. The integration of image capture, processing, monitoring and diary writing is novel and potentially powerful tool for motivating best practice self-care. Furthermore, these features adhere to recommendations from related recent studies [23, 18, 10, 9].

Concluding, the MyFootCare prototype has received promising feedback that self-tracking based on analytics of wound images can add value to the care of foot ulcers. The next step is to evaluate with a more mature application in the field.

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