SoPhy: Smart Socks for Video Consultations of Physiotherapy

Deepti Aggarwal[1], Thuong Hoang[1], Weiyi Zhang[1],
Bernd Ploderer[1,2], Frank Vetere[1], Mark Bradford[3]

[1]Microsoft Research Center for SocialNUI, University of Melbourne, Australia
[2]Electrical Engineering and Computer Science, Queensland University of Technology, Australia
[3]Department of Anaesthesia and Pain Management, Royal Children's Hospital, Australia

ABSTRACT
While physiotherapists are increasingly organizing video consultations, assessment of lower body movements over video remains a challenge. We present a wearable technology, *SoPhy* that captures and presents information related to three key aspects of lower limb movements - range of foot movement, weight distribution and foot orientation. *SoPhy* consists of a pair of socks embedded with sensors for the patients to wear, and a web-interface that displays the captured information to physiotherapists in real-time. The objective of this demonstration is to offer first-hand experience of *SoPhy* and to create conversations around designing technologies for supporting bodily communication in video consultations.

1 Introduction

Over the last decade, physiotherapists have started using video conferencing tools to offer diagnostic and therapeutic advice to patients living in remote or rural areas [2,3]. While video consultations offer several benefits to patients and clinicians, our recent study [2] highlights the limitations of video technology in communicating the essential bodily information that physiotherapists need to formulate their assessment. The study showed that the physiotherapists found it difficult to understand the subtle differences in exercises such as depth of squats, and range of movements over video, particularly, for lower limb movements. The absence of the essential bodily information reduced clinician's confidence in assessing their patients and consequently, they offered less specific treatment over video than face-to-face consultations.

The importance of communicating rich information to clinicians is always emphasized [5], as it helps clinicians in making informed decisions and thereby, making the overall consultation effective. However, lesser attention has been paid to understand how new technologies could enhance clinician's ability to assess and treat patients during video consultations. We are interested in lower limb movements as they are more challenging to communicate over video. Video conferencing tools are typically configured to support talking heads conversations, and have little consideration for the observation of full body movements [4]. Moreover, video technology possess

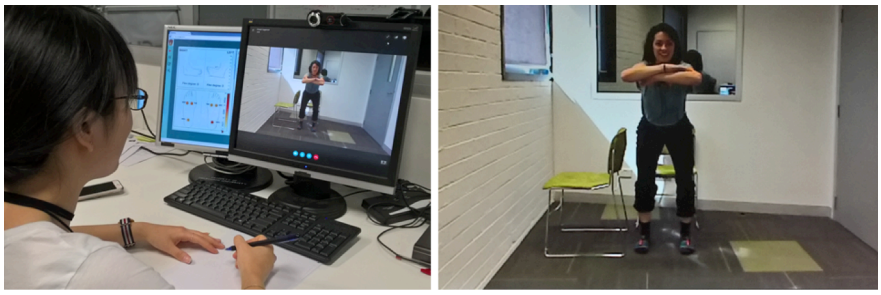

Figure 1: Setup of *SoPhy* during a video consultation: (a) In left, a physiotherapist is using *SoPhy* web-interface to understand patient's movements. (b) In right, a patient is performing lower body movements by wearing *SoPhy* socks.

limited visual acuity that further reduces clinician's ability to discern subtle changes in exercises e.g., point of balance and depth of squats [2].

This is the first attempt that extends video consultations beyond audio-video medium and explores the potential of a wearable technology to support the tasks of physiotherapists. We designed *SoPhy* that provides information of key aspects of lower limb movements during video consultations (refer Figure 1). We conducted a laboratory study to investigate how *SoPhy* helps physiotherapists in assessing patients over video [1]. The findings showed that *SoPhy* increased their confidence in assessing low limb exercises like squats, and they required fewer repetitions of exercises to assess patients with *SoPhy*. Next we illustrate the design of *SoPhy*.

2 SoPhy: Our Proposed System

SoPhy stands for 'socks for physiotherapy'. *SoPhy* is a novel wearable technology consisting of (1) a pair of socks embedded with three pressure sensors and one Inertial Measurement Unit (IMU) that patients wear while performing lower body movements (Figure 2a); and (2) a web-interface that visualizes information about weight distribution, range of foot movement and foot orientation to physiotherapists in real-time (Figure 2b).

We have followed user-centered approach to iteratively design *SoPhy*, and collaborated with a senior physiotherapist (last author) at a leading hospital in Australia. To this end, the selection of different sensors and visualisation of the data are the results of multiple lab trials and feedback from the collaborating physiotherapist. Below we describe the bodily information supported by *SoPhy*.

Weight Distribution: Weight distribution describes the amount of weight a person bears in different areas of the foot e.g., on toes, balls and heel. While a healthy person distributes equal weight on each foot (leg), the pattern changes in case of an injured. For instance, if a person has injured his big toe, he may bear more weight on the outside of the foot. *SoPhy* captures the pattern of weight distribution on the balls and heel of the foot, through pressure sensors stitched on the *SoPhy* socks. The web-interface displays weight distribution on the feet sketches showing the feet from underneath

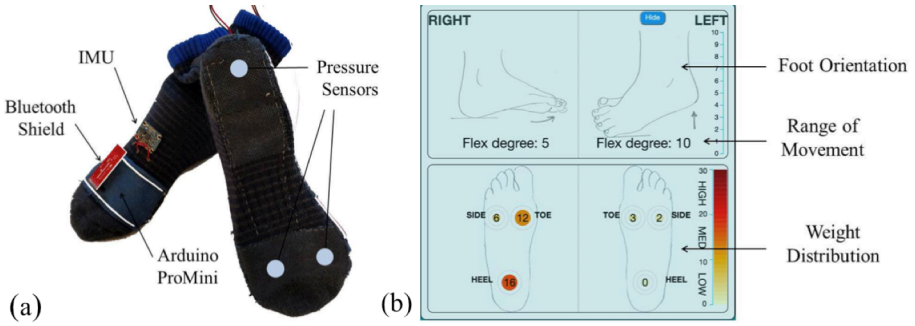

Figure 2: *SoPhy* consists of two parts: (a) a pair of socks with sensors embedded, and (b) a web-interface that visualizes the information related to foot orientation, range of movement and weight distribution.

(refer Figure 2b). For each sensor, the pressure values are presented with a number on a scale of 0-30 and on a color spectrum of yellow to red.

Foot Orientation: Foot orientation refers to the alignment of foot in four directions. First is the dorsiflexion, which occurs when the person bears weight on the heel of the foot with toes lifted up in the air. Second is the plantarflexion where the weight is on the balls and toes of the foot with heel lifted up in the air. Third is the medial orientation where the weight is on the inside of the foot and the person lifts the outside of the foot up in the air. And final orientation is lateral orientation where the person bears weight on the outside of the foot and lifts the inside of the foot up in the air. In *SoPhy*, foot orientation is captured by the IMU sensor sewed on the socks on the bridge of the foot. We have used multiple foot sketches to present this information on the web-interface: three each for dorsiflexion and plantarflexion, and two each for medial and lateral orientation (refer Figure 2b).

Range of Movement: Range of movement refers to the magnitude of the foot orientation across four directions described above. The range is defined on a scale of 1 to 10 and is calculated from the IMU data. On the web-interface, this value is represented as a 'Flex degree' under each foot (refer Figure 2b).

3 Engaging with SoPhy

Figure 1 shows the setup of *SoPhy* during a video consultation. The patient wears the *SoPhy* socks before starting the video consultation with physiotherapist. During a video consultation, physiotherapist will ask the patient to perform different lower body exercises, e.g., dorsiflexion and plantarflexion, squats, and heel raises (refer Figure 3). As the patient performs these exercises, the socks capture data about foot movements. This data is then sent to the web interface, where the physiotherapist can see the movement data in real-time. We designed a mobile app to support data communication between the socks and web interface via a Bluetooth shield attached on the *SoPhy* socks.

At the venue, visitors will be able to try out *SoPhy* in solo or in pairs. They can wear the *SoPhy* socks and check the visual feedback on the web-interface for different lower body movements. Alternatively, they can role-play as a physiotherapist and

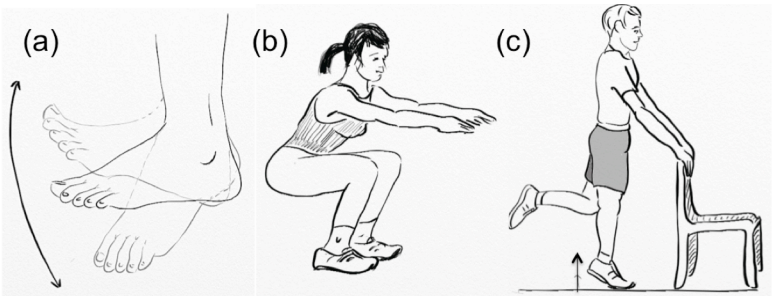

Figure 3: Examples of lower limb exercises: (a) Dorsiflexion and Plantarflexion, (b) Squats (c) Single leg heel raises.

patient, to mimic a clinical consultation related to lower limb assessment. We anticipate that audience will get the following insights by interacting with *SoPhy*:

1. They will get an awareness of the role of different bodily cues related to lower body exercises.
2. They will become familiar with the emerging practice of video consultations and the challenges of video technology in communicating lower limb movements.
3. They will gain insights on the challenges faced by physiotherapists in assessing patients during video consultations, and how *SoPhy* can help them in their decision-making process.
4. They will get a first-hand experience of *SoPhy*, which will particularly, be of interest to DIY med-tech community.
5. Finally, it will potentially seed new interests and conversations around the development of future video consultation systems that provide essential bodily information to clinicians.

4 REFERENCES

1. Aggarwal, D., Zhang, W., Hoang, T., Ploderer, B., Vetere, F., and Bradford, M. 2017. SoPhy: A Wearable Technology for Lower Limb Assessment in Video Consultations of Physiotherapy. To appear in *Proceedings of the 35th Annual ACM Conference on Human Factors in Computing Systems* (CHI'17).
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Technical Requirements

Below are our technical requirements to demonstrate *SoPhy* at the venue.

EQUIPMENT - We will need a power plug, two 24" LCD screens and a table to setup the installation.

FLOOR PLAN - Our demonstration will work in the standard booth size.

ACOUSTICAL - We do not have any special acoustical needs.

LIGHTING - We do not have any specific requirement for lighting.

TIMING OF VISITOR INTERACTIONS
The envisioned interaction with participants would be of 2-4 minutes. As described in the paper, one or two participants can try out the *SoPhy* at a time, while others can watch the demonstration in groups.

COMPUTATIONAL EQUIPMENT
We will need two 24" LCD Display screens for the demonstration.

We will also need Wi-Fi connection to communicate the data captured by the socks to the server (web-interface). We do not need much bandwidth; any speed will work for us.

RADIO FREQUENCIES - We will use Bluetooth connection to send data from the socks to the server (web-page) via a mobile app.

POWER - We will need one power socket with power extension to plug in the screens and laptop.

SAFETY- There is no safety hazards associated with our system.