mHealth Platform for the Delivery of Rehabilitation and Physical Exercise at Home for Parkinson's Disease Patients

Fernando Martínez-Martí, Samanta Villanueva-Mascato(✉), Benjamin Belletoile, Jorge Cancela, and María Teresa Arredondo

Life Supporting Technologies (LifeSTech),
Universidad Politécnica de Madrid (UPM), Madrid, Spain
{fmartinez,svillanueva}@lst.tfo.upm.es
http://www.lst.tfo.upm.es

Abstract. Parkinson's disease (PD) is a neurodegenerative and progressive disorder of the central nervous system that affects mainly the motor system. As a consequence of the disease, PD patients suffer a progressive reduction of their independence and Quality of Life (QoL). Literature research shows that the use of auditory, visual and haptic cueing could significantly benefit the motor performance of PD patients. Likewise, music therapy (MT) has shown notable benefits for PD either in the motor and non-motor dimensions. This work is aimed at designing a mHealth system to deliver a home based rehabilitation programme for PD patients based on external cueing and MT called HOOP, integrated by a set of inertial sensors, an Android application, and a web tool for professionals. This designing process has been performed according to expert's consultation in order to develop a tool that can cover both patients and professional necessities.

Keywords: Parkinson · Rehabilitation · Remote training
Rhythmic auditory stimulation · Music therapy

1 Introduction

Parkinson's disease (PD) is one of the most common neurodegenerative disorders affecting more than 1% of people older than 60 years (and with an increased prevalence in older groups). Progression of the disease is strongly correlated with higher costs – both for patients and healthcare institutions – and, even if a cure is not yet available, considerable savings can be achieved by slowing down this progression [1]. Many recent studies have shown that main motor symptoms of Parkinson's disease (bradykinesia, hypokinesia, restring tremor, rigidity, and postural instability) have an important impact in poorer Quality of Life (QoL) of PD patients, both in the mobility sub-scale of PDQ-39 and overall QoL in PD [2–4].

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In this sense, these motor abnormalities may be improved by the use of stimulation techniques that help to perform training and rehabilitation exercises such as listening to marching music. These types of techniques are called Rhythmic Auditory Stimulation (RAS) [5–7]. There are several approaches about how to use RAS and music with PD patients and healthy patients (over 65), this type of experiments are usually based on recognition of gait-health related problems [8]. Styns et al. detected that healthy young adults walked faster with music than with metronome cues [9], while Wittwer et al. found that healthy adults over 65 increased their cadence with both music and metronome, but stride length and gait velocity was increase only with music [10]. Others experiments have tested this stimulation with PD patients obtaining promising results [11].

However, most of the research works only focus on the stimulation techniques and put no effort in providing therapies to patients and combining these rehabilitation sessions within RAS techniques. Furthermore, sometimes this system does not evaluate if training therapies are done correctly. Many studies have proved the efficacy of including new technologies to promote active ageing integrating external sensors [12] and mobile applications [12,13]. This work presents HOOP, that is a platform designed to provide rehabilitation and training sessions for PD patients at home evaluating its performance, with a constant supervision of therapists and clinicians through a web system. In addition, therapist/clinician will be able to modify and personalise the training and rehabilitation sessions according to users performance, providing them a personalised therapist which will increase engagement and motivation.

2 Materials and Methods

2.1 Overall Architecture

The architecture presented in this work is based on three different modules which work together to offer an integrated mHealth tool for Parkinson's disease patients and caregivers to provide a more optimal training and rehabilitation therapies, and to be able to evaluate their performance (see Fig. 1): HOOP sensors, HOOP Therapist Website, and HOOP for Mobile.

2.2 Designing Procedure

HOOP has been designed according to a set of interviews that were carried to several participants to define requirements and needs of this mHealth tool. A total of 12 participants (4 males and 8 females) took part of the study covering different professional profiles: four therapists (three of them with experience on music therapy for PD), two occupational therapists, two neurologists, one physiologist and three biomedical engineers, all of them familiar with the use of External Rhythmical Cueing (ERC) and Music Therapy (MT) on PD. The

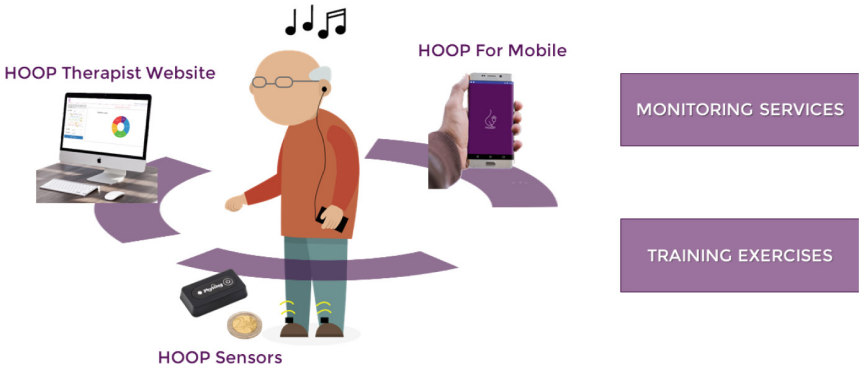


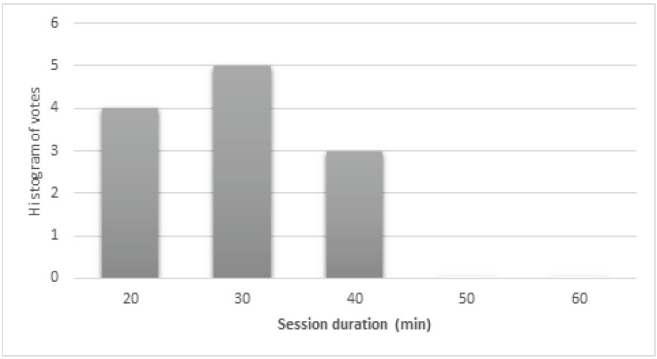
Fig. 1. HOOP architecture.

average age of the group was 35.25±9.44 years old and they presented an average of 7.33 ± 4.88 years of experience with PD patients.

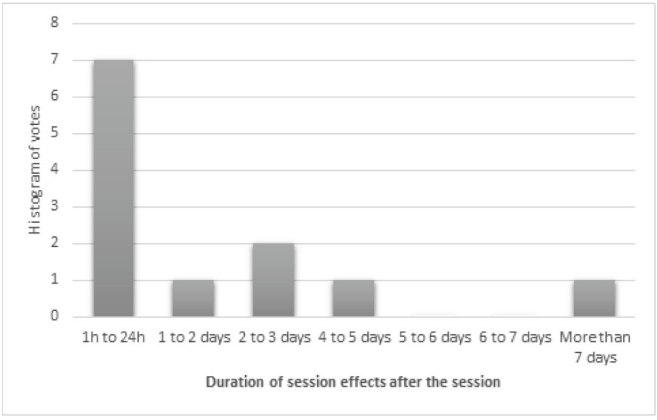
At first, experts were inquired with a set of questions regarding general aspects of how a rehabilitation programme at home for PD patients should look like. This set of questions help to identify the optimal duration for a daily gait rehabilitation sessions (Fig. 2(a)), how much time to the effects of auditory cueing and/or music therapy last after the session (Fig. 2(b)), and how to increase adherence of the patients to the rehabilitation methods (Fig. 2(c)). The aim of these questions was to adapt the development according to experts answers.

Furthermore, experts were asked (see Fig. 3) about the User Interfaces (UI) for both the patient (HOOP for Mobile) and the professional application (HOOP Therapist Website). For the patient side, a prototype of the application has been designed in Android Environment. For the assessment of the UI a variation of the System Usability Scale (SUS) [14] was used, although in this case questions were adapted to ask the experts whether they think that the patients would be able to deal with the app. The aim of this part of the work was to explore which were the therapists' needs in this scenario.

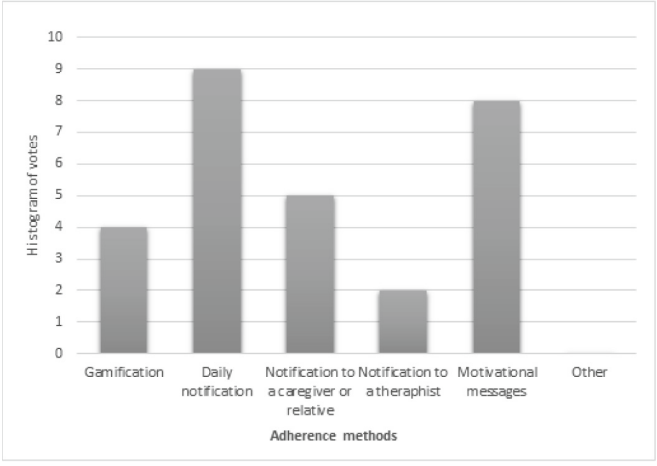
In a previous work multiple mock-ups of auditory cues were designed and explored to find out the characteristics of a Rhythmic Auditory Stimulation to be used for such purpose [15]. As a result, several aspects regarding the rhythmic, melodic and harmonic components of the auditory cues were identified in order to create new stimuli to facilitate and engage the performance of training and rehabilitation tasks.



(a)



(b)



(c)

Fig. 2. Results from questionnaires with the experts. Recommended session duration (a), duration of effects after the session (b), and the best methods to ensure adherence (c)

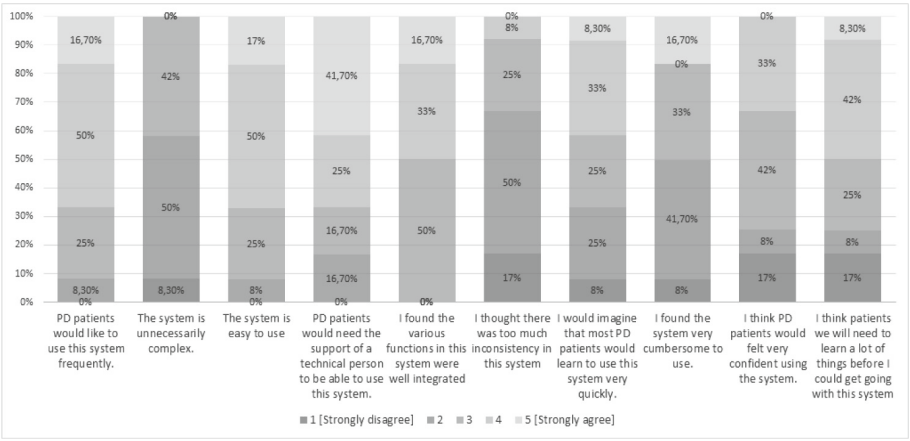


Fig. 3. Responses to the experts' opinion about the usability of the application (SUS test). Each question presents the results grouped into categories according to the experts' opinions from 1 (Strong disagree) to 5 (Strong agree).

3 Results

3.1 Sensor System

Current version of HOOP uses a set of commercial inertial sensors. These sensors are Physilog 5 (GaitUp^{TM}, Switzerland). They consist of a three axis gyroscope and three axis accelerometer, with a low energy bluetooth link, and a μSD memory card.

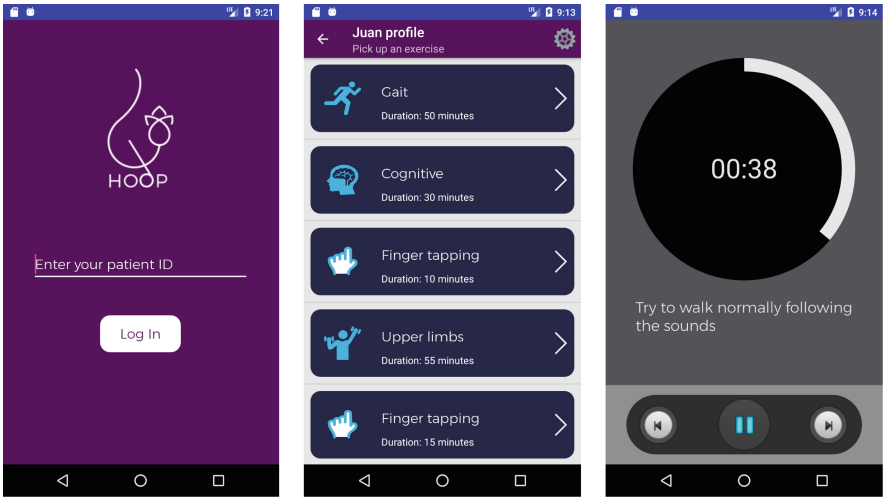
Fig. 4. HOOP sensors placement. In the wrist (a) during the upper limb training sessions and in the ankle for lower limb (b).

The use of these sensors will allow to evaluate the performance of the exercises by the clinician or therapist. They will be measure inertial movements and

compared with the exercises and music performance. Sensors will be used in pairs to distinguish left and right arm/foot. They will be located at the wrists while evaluating upper limbs exercises and in the ankles for gait training sessions (see Fig. 4).

3.2 Mobile Application

HOOP for Mobile consists in an Android Application that interacts with the Parkinson's patients and establishes a set of exercises according to the scheduled activities by the therapists and clinicians. It also will collect information from inertial sensors connected by Bluetooth in order to evaluate the correct performance of the exercises by evaluating the movement of the arms in upper limbs exercises or the steps in gait exercises. During exercises both music and cueing stimulation are provided to the patients in order to stimulate and help them to maintain a cadence performance.



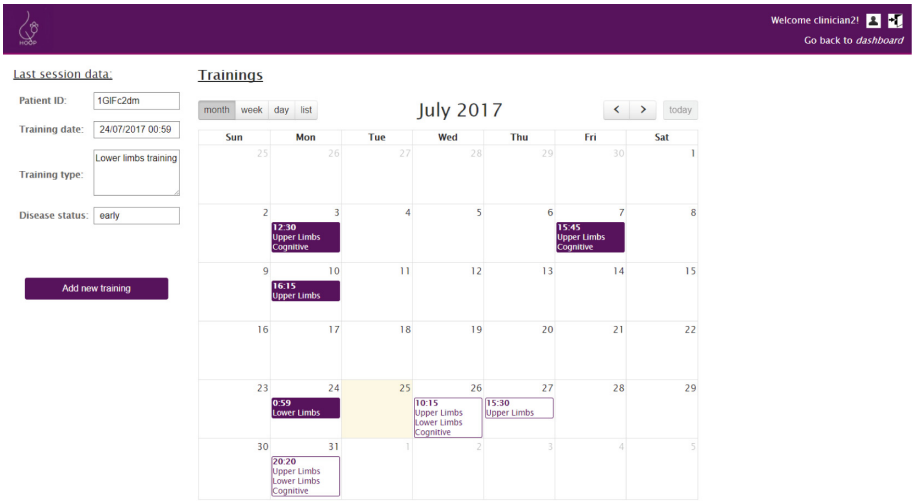
(a) Login (b) Scheduled exercises (c) Gait exercise

Fig. 5. HOOP for Mobile snapshots. Login activity (a) to identify the patient, the set of exercises (b) previously scheduled by the therapist, and the performance of a gait exercise (c).

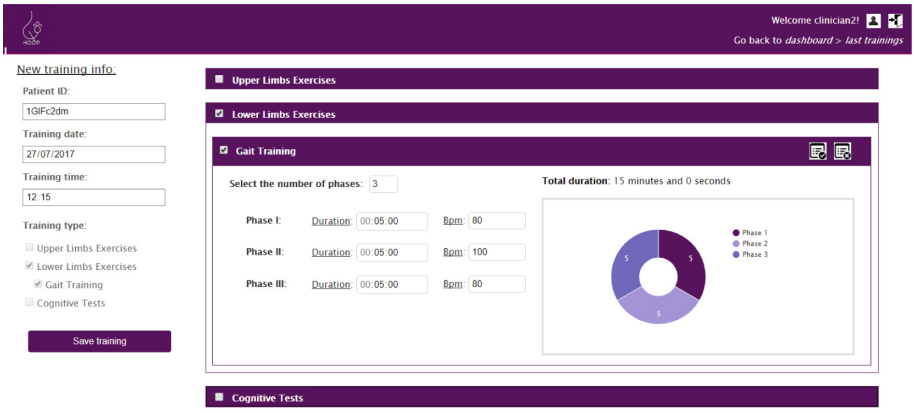
Figure 5 shows some snapshots from HOOP for Mobile application. Once the resulting information from the exercises performance is collected, it is updated in the database to allow clinician/therapist to evaluate the outcomes achieved by the patient and to establish changes in the therapy according to the patient needs, providing a more personalised therapy.

3.3 Therapist Website

The main objective of the HOOP Therapist Website is to provide a friendly user interface for the Therapists and Clinicians in order to ease their supervision tasks on those Parkinson patients who perform rehabilitation and training exercises



(a) Calendar view



(b) Create new training session

Fig. 6. HOOP Therapist Website snapshots. Calendar view (a) in which the therapist/clinician can set or edit exercises and view the results from previous training sessions. The definition of a new training session (b) which will be scheduled in the patient exercises list.

under their care. HOOP Therapist Website is implemented using Django (version 1.11.1) on top of Python (version 3.4.3) as backend, while HTML, Javascript, and CSS are used for frontend.

Every therapist or clinician is able to evaluate the performance of previous sessions (Fig. 6(a)) using the calendar view. By pressing in one of past training dates, a set of plots which are used to analyse the outcomes from the exercises allows the professional to set a new interventions by creating a new personalised set of exercises in an specific date Fig. 6(b).

4 Conclusions

According to the successful outcomes obtained for those studies which combine gait or physical therapies with auditory cueing or music stimulation, we have developed an integrated platform that eases the performance of rehabilitation and training sessions of Parkinson's disease patients at home. It is integrated by three modules: HOOP Sensors, based on a set of commercial inertial sensors, which are used to evaluate exercise performance together with mobile application; HOOP for Mobile, that is an Android application, which interacts directly with the patients, presents their scheduled activities and collects information from sensors. And finally the HOOP Therapist Website, that is a webtool for clinicians and therapists oriented to provide to professionals with tools which help them to evaluate the performance of the training sessions and to set a personalised set of exercises for Parkinson's disease patients with the goal to reduce the impact of motor symptoms and them, improve their quality of life.

The design and development of HOOP have been performed according to experts opinion. A set of questions has been given to compile information about what are the needs of typical rehabilitation and training sessions for Parkinson's disease patients to adapt the architecture and design to these requirements. And once the application was done, an usability test was prepared to evaluate the opinion from these groups of experts not only about patient application but also clinician web application. Obtaining in both case very good results that shows promising results for the validation with PD patients.

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