Demo: STOP: A Smartphone-based Game for Parkinson's Disease Medication Adherence

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Abstract
Parkinson's disease (PD) is a second most common neurological disorder that affects up to 10 million people worldwide. It has an evolving nature and the symptoms may vary from patient to patient. Thus, to increase the effectiveness of PD treatment, it is necessary a personalized medication plan. Currently, PD patients undergo symptom observation on semiannual clinical visits. This work aims at the development of a new way of observation via smartphones, while at the same time offering the PD patient a tool to better understand his medication needs. Our mobile application leverages smartphone's inbuilt sensors in order to keep track of subject's medication adherence throughout the day, taking shape as a short-term accelerometer-based game played several times a day, and allows PD patients to record when they took medication. The combination of collected datasets can be used in further studies in order to estimate the changes in PD severity and medication effectiveness over time.

Author Keywords
Parkinson's disease, smartphone, gamification, instrumentation

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

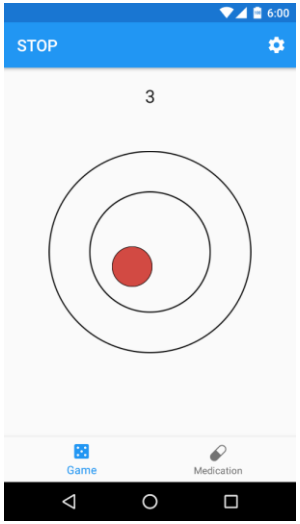

Figure 1: Game interface

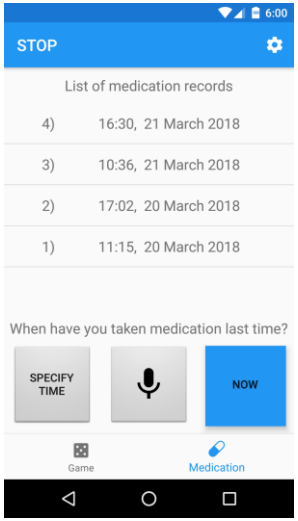

Figure 2: Medication journal

Introduction

Parkinson's disease (PD) is a progressive neurological disorder that influences human movement functionalities and complicates patients' daily life. PD has an effect on both the patient's physical and mental health status – along with tremor, slowing down and obstruction of body movements, it also becomes a reason for psychological and behavioral changes that break the subjects' routine [9]. However, despite serios impact of the disease, there is still no universal and effective treatment method.

Implementation

The main goal of this research study is to design a tool that will be useful in continuous PD patient observation and will motivate them to better understand their medication adherence throughout the day. The application is designed as a combination of two components: an accelerometer-based ball game (Figure 1), that handles PD effect measurement process; and a medication journal (Figure 2). The collected datasets provided by the regular use of the application can be utilized for analyzing the correlation between the medication effect and PD severity level during a day [3].

Accelerometer-based ball game

PD main symptoms are involuntary shaking. The gamified component of STOP is a simple accelerometer-based game that leverages device's sensors and represents user's hand movements as the ball's movement on a device screen. When a user tilts his own device forward, backward, left or right, the ball on the screen moves accordingly in the same direction, simulating gravity. Thus, the game makes it possible to observe tremors' severity of a patient via short-term game sessions during the day. The game interface, which is shown in Figure 1, consists of the ball, two boundary circles, and the timer that shows the stage status of the game. The game players' goal is to keep the ball as close as possible to the center of the inner circle for a defined time interval. The game is designed in a way to be used as a short-term gamified session that collects acceleration data from the hand's movement of the patient and translates it to the scoring system. The game has a set of customizable parameters: the size of the gaming ball and auxiliary circles, the speed of the ball and the length of the game can be modified and adapted to each patient individually. The provided flexibility in the use of the game allows estimating the severity of patients' tremor in various conditions.

Medication journal

To meaningfully correlate the game statistics with the patient's condition, there is a need to monitor patient's medication intake during the day. Hence, the second application component, medication journal, has been developed. The journal allows a user to record when they took their medication. The interface of the journal is shown in Figure 2. It is composed of a list of previously recorded medications and three buttons that are used for timestamp input.

Smartphone's sensors and data collection

The previous studies [7,10] show that it is possible to leverage smartphones inbuilt sensors for PD observation. STOP uses smartphone's accelerometer as the basis for the game component: the movement functionalities of the playing ball that represents user hands activities are implemented with the use of it. Moreover, during the game session, the application activates and collects data from three more sensors: linear accelerometer, rotation, and gyroscope. The collected dataset is initially saved to smartphone's

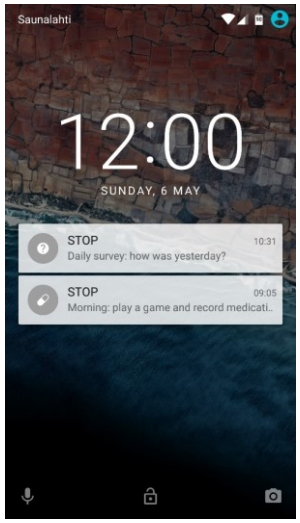

Figure 3: Reminder notifications

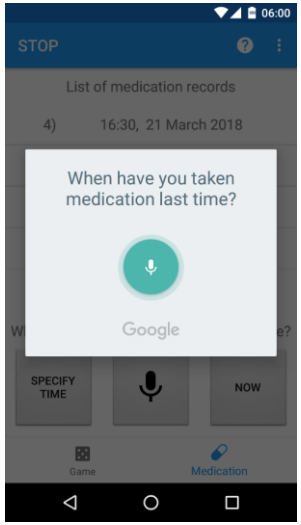

Figure 4: Reminder notifications

memory and later synchronized to a remote server provided by AWARE framework [5]. The application collects only motion-related and medication takings time data, no user sensitive data is collected.

User-centered design strategies

In order to improve the convenience of use and user experience, the application design takes into consideration PD patients' finger dextery and several user-centered design strategies are used. First of all, with the purpose of regular following health observation, the application utilizes Android notifications component [1] as a reminder strategy that increases the user's involvement and recalls the patients to use the application on a regular basis (Figure 3). Secondly, the application design takes into account PD effects, such as tremor, so the control buttons are implemented in big size and represent the clicking effect with a different color, that makes the experience more understandable (Figure 2). Finally, along with the manual input, the application supports the data input by voice (Figure 4) with the help of Android's speech recognizing component [2] and natural language processor provided by Wit.ai [11]. It automatically transcribes the user's speech commands like "two hours ago" and "yesterday 10 p.m." in a Unix timestamp format. This approach allows to avoid the complexities with manual input for PD patients and avoid excessive typo errors.

Evaluation

The application was evaluated with a pilot study with ten male volunteers aged from 22 to 41, with no known symptoms or conditions of PD. This dataset acts as a baseline for non-PD for future work. The participants were asked to play the game several times with various settings combinations. Next, the participants were asked to rank the game in a 1 (low) – 5 (high) scale with regards the following heuristics: ease of use, user engagement and perceived usefulness for PD tracking. The results of the heuristics showed that on the average participants ranked the game as 5 for ease of use, 4 for user engagement and 5 for perceived usefulness for PD tracking. The detailed rankings are shown in Table 1.

Participant №	1	2	3	4	5	6	7	8	9	10
Age	23	25	29	35	35	31	27	41	34	22
Ease of use	5	4	5	5	5	4	5	5	5	5
Engagement	4	4	4	4	4	3	4	5	3	4
Usefulness for PD	5	4	5	1	5	4	5	5	4	4

Table 1: Plot study: app usability evaluation (1=low, 5=high)

The participants played 216 game sessions in total. The boxplot for the game results is illustrated in Figure 5. The following descriptive statistics were discovered from the collected dataset: the median game score is 97.9; the maximum score is 99.7; the minimum score is 91.2; standard score deviation is 1.48. Therefore, it is possible to say that a non-PD user gets the game score between 96.8 and 98.4 with any game parameter combination.

Discussion & Conclusion

In spite of the vast prevalence of PD worldwide and its evolving nature, the current way of patient observation is not applicable for personal treatment plan customization, which results in low effectiveness of treatment in general [8]. This study utilizes the accessibility of smartphones nowadays and develops the mobile application "STOP" that can be used for patient observation on a regular basis. Based on the related work [4,6], the application applies gamification method to sampling process in order to increase the patients'

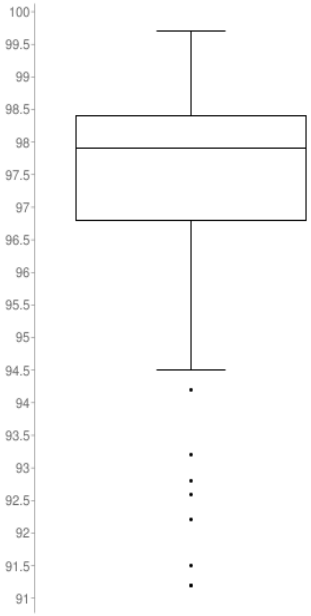

Figure 5: Game score results boxplot for 216 games played during the pilot study

engagement. This study demonstrates the advantages of smartphones use in continuous PD observation. The application is designed for Android and iOS platforms. After the testing period among PD patients [3], the application will be released in Google Play and App Store to collect the largest dataset openly available for PD specialists, to better understand the complexities of medication and Parkinson's.

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