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User Interaction

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6.1 Introduction

One of the components of the REMPARK system is the smartphone, which represents the main communication channel between the system and the user. Within the project, the main goals in the development of the smartphone applications were to complement and confirm information coming from the system's sensors through patient feedback tests and to design user interfaces specifically tailored to the needs and abilities of users with Parkinson's Disease (PD).

Given the nature of a device such as the smartphone and its potential benefits in daily life outside a medical scope, the design and development went beyond the single focus on medical issues to encompass other services, such as the usual communication features offered by a smartphone.

The need for a strong collaboration with end-users was defined at the project onset, which led to an iterative design process. This not only informed choices about patterns of interaction suited for people with Parkinson's Disease (PwP), such as target sizes or suitable gestures, but also about the kind of features main stakeholders would like to see in the REMPARK smartphone. The structure of this chapter will then reflect the two main blocks mentioned above: 1) the research on guidelines regarding visual, interaction and navigation patterns; and 2) the design and validation of the smartphone applications.

The smartphone is increasingly recognized as a viable instrument to be applied in medical diseases with movement disorders [1]. Main applications currently refer to the possibility of monitoring symptom changes over time through the use of relatively economic software. This could potentially

represent a significant advance particularly for the management of chronic conditions.

The direct use of smartphones with PD patients should take into account the presence of the motor and non-motor symptoms that could potentially affect the usability of the smartphone applications. It should also be noted that people involved in REMPARK were, mainly, older adults. It was then taken into account that these individuals might not show high familiarity with smartphones, and, more generally, with the use of most modern technologies.

With the exception of a few studies regarding interaction of PwP with desktop solutions or desktop peripherals [2, 3], software [4] or pen-tablet devices [5, 6], at the beginning of project activities, there were few studies on the interaction of PwP with smartphones. There were official guidelines for the sizing of target buttons for people with disabilities and studies on both the sizing and element gap for people with disabilities [7]. Nevertheless, none specifically focused on PwP. This, then, constituted an opportunity for relevant research on and beyond the scope of the REMPARK project, which would likely:

1. help future practice in the development of ICT solutions for this particular target group;
2. help the development of more inclusive guidelines;
3. help contribute to reducing the digital divide through promoting enhanced access to smartphone solutions.

The sub-goals defined for this task were:

- to find suitable patterns for the REMPARK smartphone applications which would enhance accessibility and usability;
- to design the applications themselves under collaborative processes with users so that these applications would be: easily used by people with PD, non-stigmatizing, user-friendly and foster adherence to the medical treatment.

All the user interfaces were successfully designed and the most relevant issues evaluated with end-users. The process also took into account possible extensions to the REMPARK services, which led to specific user interfaces leaving room to future features and additions. The results from the field trials are listed and discussed in this chapter, followed by possibilities for future work.

6.2 State of the Art/Competitive Analysis

As part of the REMPARK activities, a systematic search was conducted in order to capture and analyse relevant information about mobile applications that could assist PwP in managing the disease. The search was organized to find market products and Research & Development (R&D) technology related to this topic, including technology being developed and described in published and publicly available papers and conference proceedings. The search also included currently registered patents to verify the existence of innovative solutions. In terms of products or prototypes, the search was limited to mobile solutions for either Android or iOS smartphones.

Table 6.1 summarizes the results of said search for R&D and market-ready products. The different evaluated parameters are those appearing in the top row of the table.

Some applications, like *Parkinson's Central*, the *Parkinson's Disease by WAGmog* and *Parkinson's Disease Facts* are small applications that provide very useful information about the disease, but do not contemplate any kind of interaction with the user. *PD Warrior* also offers information about the disease and combines it with rehabilitation exercises. *Parkinson's Home Exercises* focuses on the physical side of the disease, providing rehabilitation exercises and cueing support. It does not address the psychological and disease managing sides. *Parkinson's Disease Manager* is an application that provides a relation between the doctor and the patient. It has doctor reminders and questionnaires that allow the doctor to better diagnose the state of the disease continuously.

DAF Professional, *Speech Companion* and *Parkinson's Speech Aid* solely focus on speech therapy, and no other application has approached this method in conjunction with other features. It is an innovative method that is rising among the possible therapies for PD. The *Apple Health Kit* is the only solution we found that can assess PD stage by analysing the voice of the patient. It also covers other features like recording all motor data, questionnaires and, like REMPARK, the Tap games.

Parkinson's Easy Call is the only solution we have found that overhauled the default smartphone applications and adapted them to users with PD. However, it does not include any other extra feature.

Some applications, like *ListenMee*, *Musical Therapy Service Portland*, *MoveApp* and *Beats Medical Parkinson's Treatment* contain an auditory cueing solution; however the last two also incorporated a few extra features. *Beats MedicalTM* also tracks medical intake history and the *MoveApp* is one

Apple Health Kit ¹⁶	x	x	x	✓	✓	x	x	x	✓	x	✓	x	✓	✓
Beats Medical Parkinsons Treatment ¹⁷	✓	x	x	x	Physical Activity	x	x	x	x	✓	x	x	x	x
Track intake history					Manual									
ParkinsonMeter ¹⁸	x	x	x	x	✓	x	x	x	x	x	x	x	x	x
Parkinson's Diary ¹⁹	x	x	x	x	✓	x	x	x	x	x	x	x	x	x
Parkinson Info App ²⁰	x	✓	x	x	x	x	x	x	x	x	x	x	x	x
Parkinson's Speech Aid ²¹	x	x	x	x	x	x	✓	x	x	x	x	x	x	x

¹<https://play.google.com/store/apps/details?id=com.apps.parkinsons>

²<https://play.google.com/store/apps/details?id=nl.efox.parkinsons.en.phone>

³<https://itunes.apple.com/us/app/my-parkinsons-disease-manager/id953530845?mt=8>

⁴<https://play.google.com/store/apps/details?id=com.speechtools.DAFFPro>

⁵<https://play.google.com/store/apps/details?id=co.uk.org.parkinsons>

⁶<https://play.google.com/store/apps/details?id=com.quizmine.parkinsonsdisease>

⁷<https://play.google.com/store/apps/details?id=com.andromo.dev77961.app379765>

⁸<https://play.google.com/store/apps/details?id=com.droidbd.pdwarrior>

⁹<https://play.google.com/store/apps/details?id=com.brainmee.listennee>

¹⁰<https://play.google.com/store/apps/details?id=com.intel.aa.medisense.android>

¹¹<https://play.google.com/store/apps/details?id=com.al67929799052318630ed3072a.a17422189a>

¹²<https://play.google.com/store/apps/details?id=de.speechcare.moveapp>

¹³<https://play.google.com/store/apps/details?id=com.medando.speechcompanion>

¹⁴<https://itunes.apple.com/us/app/pd-life/id430413808>

¹⁵<https://itunes.apple.com/us/app/parkinson-info-app/id397358632>

¹⁶<https://www.apple.com/ios/whats-new/health/>

¹⁷<https://www.appannie.com/apps/ios/app/parkinsonmeter/>

¹⁸<https://www.appannie.com/apps/ios/app/parkinsonmeter/>

¹⁹<https://www.appannie.com/apps/ios/app/parkinsons-diary/>

²⁰<https://www.appannie.com/apps/ios/app/parkinson-info-app/>

²¹<https://www.appannie.com/apps/ios/app/parkinsons-speech-aid/>

of the most complete solutions found that includes medication reminders, information about PD, a diary, rehabilitation exercises, an auditory cueing solution and questionnaires. There seems to have been less focus on the usability of the system in favour of the rehabilitation methods.

The *Fox Insight App* focuses on the daily management of the disease with medication reminders and a diary. This information is combined with a record of all motor data detected by the smartphone.

In the course of the chapter, it will become clear that, overall, the REMPARK system offers most of the features represented by all solutions, however it has more focus on the management of the disease, physical and psychological monitoring and improvement of patient Quality of Life (QoL) while using the smartphone applications actively or passively. It does not have any kind of approach regarding rehabilitation or speech related techniques. It also does not provide any kind of general information about the disease. While the lack of these features may be seen as a downside of REMPARK, it is important to state that the REMPARK system was developed as a monitoring system with an Auditory Cueing System (ACS) as actuator that offers assistance in case motor symptoms are detected.

The search in patent databases retrieved the following relevant examples:

- WO2011088307 A2 (Application, filing date 2011) [8]. “A medical monitoring and surveillance system uses a server communicating with a general purpose personal device running an application. The application may be downloadable. The application is configured by the server, i.e. the application configures the device to perform medical tests using the sensors, pre-existing capabilities, and functionality built into the device. The device may be a cellular phone with data communication and other functionality, a personal digital organizer, a portable entertainment device, or another similar personal device. The application reports the results of the medical tests to the server or a third-party device. Various trigger events and associated tasks may be incorporated in the server or in the application residing on the device. A trigger event may occur, for example, in response to the test results meeting one or more predetermined criteria. Once a trigger event occurs, a task associated with the trigger event is performed.”
- US8669864 B1 (Grant, filing date 2013). [9] “A mobile terminal is used to assist individuals with disabilities. A mobile terminal such as a “smartphone” or other commercially available wireless handheld device may be loaded with software. The software may be configured to: (i) store

criteria for managing communications between a disabled user of the mobile terminal and a remote caregiver, (ii) determine whether a criterion is satisfied, and if so (iii) initiate a communication from the mobile terminal to the remote caregiver, and (iv) receive a response from the remote caregiver. Thus, through this software, the mobile terminal may dynamically facilitate communications with specific remote caregivers based on specific situations that may confront disabled individuals.”

- US20130345524 A1 (Application, filing date 2013). [10] “Methods and systems are disclosed for sensing and assessing patients’ responses to tests using a device that may include tactile input, voice input, still image analysis, and responses to visual and auditory stimuli. In one example, a method includes obtaining interactive clinical assessment data using a remote client device and a computer-based control device, the method including providing on a display of a remote client device one or more test prompts for conducting an interactive clinical assessment, each displayed test prompt instructing a user to perform an action using the remote client device in response to the test prompt, and providing on the display of the remote client device one or more potential responses of actions that may be performed in response to the test prompt.”

Analysing the patents found, it is possible to see that none is completely oriented to PwP, however all three describe different methods to manage a system similar to REMPARK. WO2011088307 A2 describes a system similar to REMPARK where a smartphone gathers data from different devices and sends it to the server. After that, some triggers may be configured in both the server and the smartphone. The REMPARK system works differently, as the triggers are preconfigured and the server only calculates the thresholds that activate them. The US8669864 B1 patent describes a simple system of communication between caregivers and patients, also not focusing in PwP. Their focus was in general disabled people, and therefore the applications are adapted accordingly. Given that REMPARK is a monitoring system, the communication between the caregiver and the patient, using the tools developed for REMPARK, is strictly restricted to the management of the disease (medication intakes, medical appointments scheduling, etc.), even though the patient may use REMPARK’s smartphone as a normal phone in his/her daily living to establish and receive phone calls, text messages, access the Internet, etc. The last patent (US20130345524 A1) describes the usage of a device’s input methods, like touch, voice, gestures, etc. and how they can be used to perform an interactive clinical assessment. The REMPARK system makes use of this method in the Tap games.

6.3 Interaction Guidelines for Users with Parkinson's Disease

The first step towards the design of adequate user interfaces for PwP was understanding which and how specific symptoms of the disease affect the interaction with touchscreen handheld devices such as smartphones; secondly, understanding how said interaction with the smartphone can be improved in order to accommodate the characteristics of the disease [11].

After an intensive literature review on the topic, eight semi-structured interviews with health care professionals who worked with PwP on a daily basis were organized. They were complemented with observation sessions in which two PwP showed their symptoms to their neurologist, as if it was a consultation. The interviews were audio-recorded, coded and analysed, which enabled to understand which symptoms of PD could affect the interaction with the smartphone. Table 6.2 shows some interesting Interview Results (IR) to be considered.

To actually measure the extent to which PD symptoms affect the interaction with the smartphone, usability experiments were created. Thirty-nine participants (17 females, 22 males) took part of the usability experiments. Participants average age was 64 (Median: 66; STD: 7.4) and had been diagnosed as having PD since for at least 10 years (Median: 8; STD: 5.8).

Table 6.2 Some important interview results

Motor Characteristics	
IR1	Bradykinesia can slow repetitive movements.
IR2	Rigidity makes interaction more imprecise and slower.
IR3	Dyskinesia can make the interaction very difficult.
IR4	PD may hinder speech.
IR5	Some PwP may experience visual disabilities.
IR6	PwP are likely to use the phone while standing still or sitting.
IR7	The impact of PD hands' tremor is limited.
Cognitive Characteristics	
IR1	Short-term memory loss is accentuated on PwP.
IR2	Thought is slowed by PD.
IR3	Depression and apathy are common in PD.
IR4	Dementia cases are often observed on later stages of the disease.
General Characteristics	
IR1	Symptoms significantly vary across different PwP.
IR2	Symptoms vary between ON and OFF phases.
IR3	The disease progresses differently from person to person.
IR4	Autonomy is gradually lost.

All participants took part of the experiment while in ON phase. Regarding participant's self-reported motor symptoms: 59% had tremor, 59% had rigidity, and 26% had dyskinesia. Some of them (13%) had undergone deep brain stimulation surgery. The recruitment was done through two delegations of the Parkinson's disease patient association in Porto and Lisbon, as well as the Hospital of São João (Porto) in Portugal.

As it can be seen in Figure 6.1, four different tests were developed to evaluate the following PwP abilities:

1. select targets of different sizes using the Tap gesture
2. do swipes
3. perform repetitive taps
4. accomplish drag gestures

Tap and Swipe were chosen due to their heavy use on today's smartphones. Multiple-tap and Drag were chosen because they were adequate for building smartphone interfaces for medical questionnaires with scales, a requirement of

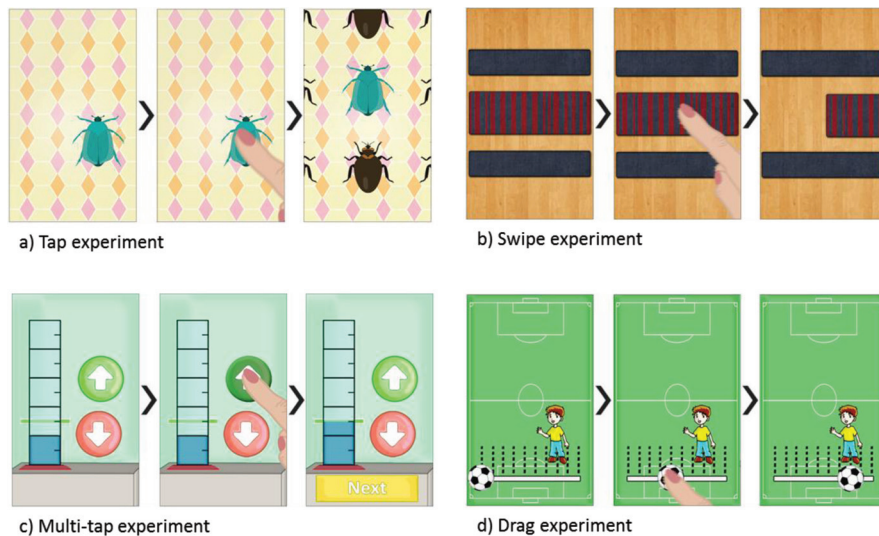


Figure 6.1 Sequence of interaction of different experiments. a) Participants had to touch the target, which appeared in different sizes, at different positions and surrounded by distractions of different sizes; b) Participants had to slide a rug which appeared in different heights with different spaces to the distractions; c) Participants had to control the water level, by filling the pipette by touching the arrow up until the water reached the green mark; d) Participants had to use the seek bar with a ball as a selector to drag the ball to the boy; scale and mark's position changed with test progression.

the REMPARK project. Experiments were developed for the Android platform and designed to run on the Samsung Google Nexus S (4-inch capacitive touchscreen, with 480×480 pixels of resolution and $123.9 \times 63 \times 10.9$ mm dimensions). All relevant interaction data were logged during the experiments and conveniently analysed.

The results of the usability experiment showed that Tap test results were significant both regarding touch accuracy and reaction time. The results showed that mean touch accuracy tends to decrease with button size, and the highest accuracies were observed with targets with 14 mm size (98% of accuracy). Results also showed that the spacing to surrounding elements does not influence the accuracy of the Tap.

It was observed that PwP are able to perform swipes and distinct participants swipe at very different speeds. Despite target size and spacing between the target and surrounding elements being irrelevant, our results showed that to accommodate 95% of the participants' swipes one should accept movements of 24 mm/s.

PwP were also able to perform successive taps with no significant reduction in speed, which challenged the data from the interviews that anticipated PwP would be strongly affected by bradykinesia. However, as participants performed the tests while in ON phase, this might not be the case.

Regarding the Drag gestures, it was shown that participants were able to drag objects with precision, but they were slow to reach the goal. However, the increased frustration expressed by the participants with the Drag, allows us to say that Multiple-tap is more comfortable to perform than Drag.

By reflecting on the findings of this short study, 12 user interface design guidelines (DG) for creating smartphone applications for PwP were considered and are listed in Table 6.3.

Table 6.3 User interface design guidelines

Design Guidelines	
DG1	Use tap targets with 14 mm of side.
DG2	Use the swipe gesture, preferably without activation speed.
DG3	Employ controls that use multiple-taps.
DG4	Use drag gesture with parsimony.
DG5	Prefer multiple-tap over drag.
DG6	Adapt interfaces to the momentary characteristics of the user.
DG7	Use high contrast coloured elements.
DG8	Select the information to display carefully.

Table 6.3 Continued

DG9	Provide clear information of current location at all times.
DG10	Avoid time dependent controls.
DG11	Prefer multi-modality over a single interaction medium.
DG12	Consider smartphone design guidelines for older adults.

6.4 User Research and User-Centred Design Processes

The choice was to provide the users of the REMPARK system not only with the REMPARK applications, but also common functionalities of mobile phones. The REMPARK applications could have been designed as stand-alone applications which could be downloaded and be amongst the smartphone's existing applications. Two performance-based reasons discouraged this approach:

1. The REMPARK system is a medical one containing sensors and actuators which play a serious role in users' lives. Therefore, the system should have some control over its performance, which means having, amongst others, control over battery duration or some means of preventing external applications' interference with REMPARK's applications.
2. As described in the previous sections, users with PD are generally older adults who, nowadays, are likely to be less tech-savvy and who, additionally, due to the disease itself, have motor and non-motor constraints which might hinder the interaction with the smartphone. These users then require simple user interfaces which are furthermore adapted to their abilities.

These reasons have led the partners to develop a set of applications which would work within a launcher. In a nutshell, launchers enable developers to create a custom home screen through which one also has the possibility to control what the user will or will not see and interact with. The advantage of the launcher is that it answers the above listed reasons in the sense that it allows to control which applications the user has access to and, furthermore, in what usability and user experience are concerned, it allows for the design of a single interaction experience. All applications within the launcher obey the same principles and patterns and, once the user has learned how to use one, he or she will most likely be able to use the others, as the language is kept identical.

The processes followed a human-centred approach in that main stakeholders were called to be part of the design process from onset. Following the above

described reasoning, the initial list of applications to design and implement within REMPARK was set amongst the partners in the consortium as follows:

- Messaging
- Emergency call
- Calling
- Contacts
- Show disease status
- Medication
- Agenda
- Auditory Cueing System (ACS) controller
- Medical questionnaires
- My data
- Settings
- Tutorials

After this definition, a process of interaction with users was scheduled in order to cope with main usability requirements, not previously considered.

Apart from the health-related benefits arising from the ACS, the value proposition for this set of REMPARK applications would be that PwP could have all their Parkinson's-related mobile needs satisfied, while not hindering the use of the main purpose of a smartphone: communication. All aspects of the applications – ranging from button sizes to workflows – were taken into account from users' perspective in order to insure a positive user experience.

After informal discussions with the experts within the REMPARK project, who provided insights about PwP's needs and abilities, app design was approached first through an exploratory methodology, in semi-structured interviews to people with Parkinson's disease, informal caregivers and physical therapists. The analysis of these results informed a second phase for which a collaborative and participatory approach was considered, mainly involving people with Parkinson's disease and their caregivers.

The results were not conclusive regarding most issues (medication/ appointment reminders, preferred activities or physical therapy). On the one hand the samples were fairly small and, on the other hand, participants with PD gave ambiguous answers to the questions posed by the researcher. Nevertheless, there was a clear concern with moving around outside (especially in places further away from home) and with having emergency mechanisms at PwP's disposal in case something happens.

These interviews helped to structure the next steps in user research and to add a new requirement for the smartphone: that it should provide others the information that the smartphone owner has PD.

The material up until this point had enabled the design of the user interfaces and some screen flows. The choices for the UIs and, specifically, the GUIs were made based on Fraunhofer Portugal's existing knowledge and expertise on UIs for older adults, topped with the findings regarding specific requirements for users with PD.

The background was kept dark to prevent glare and increase battery life and all buttons size complied with the recommendations mentioned in Table 6.3. The approach was to avoid the need for scrolling actions to the widest extent possible. Therefore, activities were sometimes divided into layers and, consequently, sub-activities. All screens consistently displayed the same Back button, appearing at all times and in the same location. All action buttons were consistent in displaying, whenever possible, an icon along with an action verb + name, so that the user would be surer of his or her input. For instance, whenever possible, instead of "Save", the button would read action verb plus the element being saved, e.g. "Save Appointment".

Regarding navigation, the screen flows were kept with as few layers as possible, wording was sought to adapt to terms which were familiar to users and which could have relation to the physical world. For the composition of the screens we have opted to design a set of patterns for a number of situations/functions, which allowed to be grouped according to each situation. Figure 6.2 shows some examples of the designed patterns.

In order to allow for as simple as possible an interaction, the text input created a new activity so as to allow for a simple screen which would not demand too much of the users' attention. As seen in Figure 6.3, once activating a textbox, the user is led to a screen with a title reminding the input action, a textbox, a save button and the keyboard. In this way, the user was offered step-by-step guidance on information input.

Scoping sessions with stakeholders provided additional ideas for features which would enhance the REMPARK smartphone, such as the different ways to trigger an emergency alert, the importance of showing information about the disease, along with some clues on what to show, the importance of having clear information on medication reminders in order to reduce error, or the usefulness of keeping a detailed record which both the medical doctor and the PwP/caregivers can consult.

With all the compiled information and generated inputs, the partners proceeded to redefine parameters in the REMPARK applications. At this time, the screen flows for the following applications had been re-defined:

- Medication
- appointments

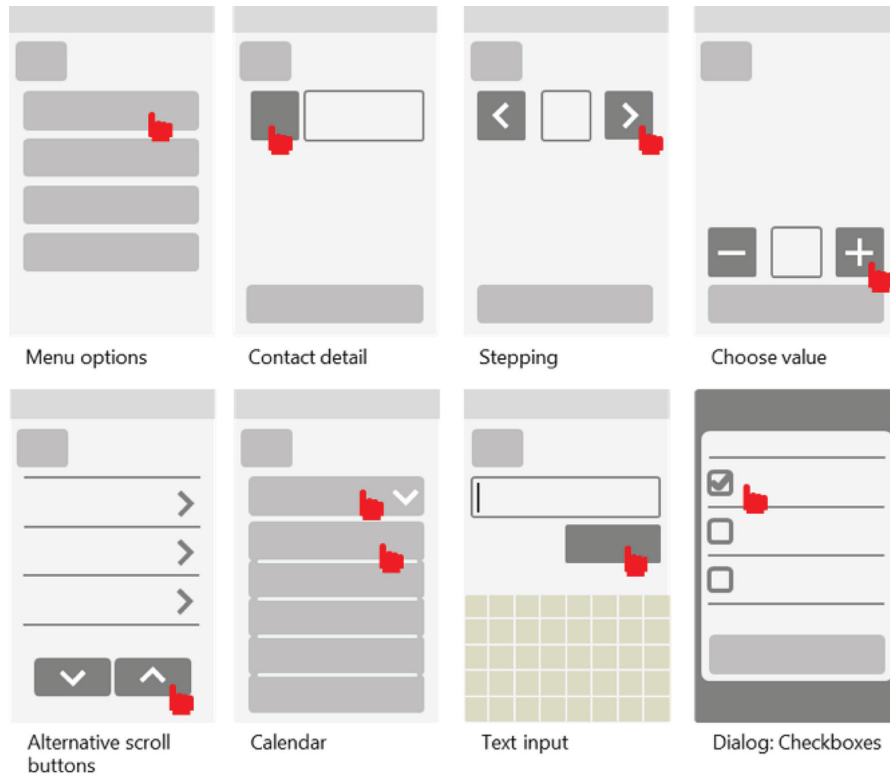


Figure 6.2 Some examples of UI patterns and gestures.

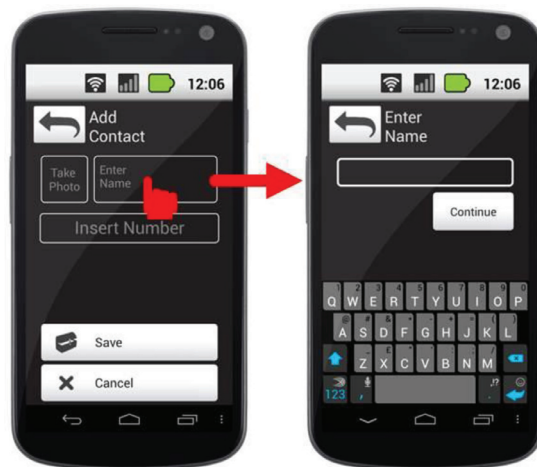


Figure 6.3 Sequence for text input.

- calls
- messages
- contacts
- ‘my data’.

A specific interaction session with PwP was organized at this point with the objective of clarifying some issues within the medication application, namely the amount and type of information being displayed (in *medication*, *disease status*, *appointments* and *my data* applications) and to check whether or not the flow was easily followed. The session also aimed to discuss the options for emergency calls with the participants, the option of having SMS templates and the option for the appointments application to have a rough prediction of OFF states. Finally, participants were asked about what they thought would be the best icon for the Auditory Cueing System controller. Some comments on this session:

- **About the medication.** Participants were asked to state their opinions regarding the proposed solutions and also to contribute with their critical thinking and experience with the disease. For the most part, the solutions were welcomed by participants with minor remarks. For instance, regarding the ‘Medication Details’, participants thought there would be no point in displaying the name of the active substance along with the medication name. Participants agreed that the possibility to add notes to the medication details was useful and that these should show on the reminders (e.g. ‘Sinemet 10/100 mg, Take before eating’).
- **About emergency situations.** Facilitators discussed the ideas of having one lateral hardware button reconfigured to act as quick dial to an emergency number on long press. They also discussed the quick dial to a caregiver and the permanent presence of a quick dial to an emergency number through an icon on the smartphone’s main screens as it is shown in Figure 6.4. Participants tried out long presses to the lateral hardware buttons and agreed that it would be an easy action for them to complete. They envisioned that a possible use case would be an emergency during bathing.
- **On “My data”.** Participants were also happy about the possibility to have a quick access to their health information under ‘My Data’. At this point in time, the ‘My Data’ flow would first show a pop-up with a warning to inform that the smartphone owner had PD, followed by a screen with the owner’s picture, a quick dial button to the caregiver and a list of current medication. Participants mostly cherished the possibility to carry with them the list of medication they were under at any point in time.



Figure 6.4 Screenshots of the home screens: Applications screen (to the left) and Favourites screen (to the right).

After the advice of medical partners, the adopted solution is presented in Figure 6.5, where all relevant information is shown at once (preferable avoiding scroll).

- **On the Disease Status.** Participants welcomed the idea of visualizing their disease status. They would appreciate it if the application would be able to record involuntary movements (dyskinesia). One caregiver in the

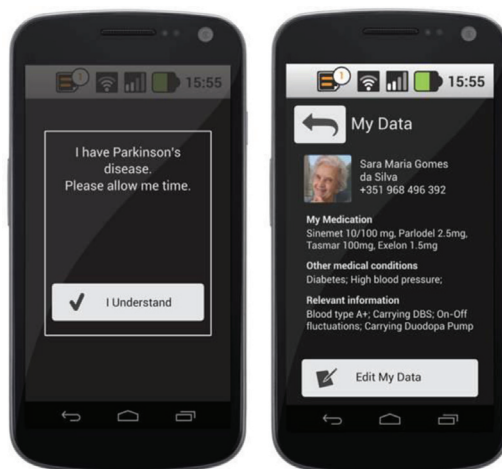


Figure 6.5 Screen flow for the 'My Data' application.

group had already her paper version of this disease status visualization, which she would take with her every time she accompanied her sister (PwP) to the doctor.

According with medical partners, one of the main drivers for choosing to include such an application was to promote treatment compliance. Several studies show the nefarious consequences brought about by non-compliance with medical treatments [12, 13]; nevertheless, controlling medical compliance without being intrusive and tiresome to users is a difficult task. Our hypothesis was that, by allowing users to easily visualize the relation between their disease status and their medical treatment adherence, they would be compelled to follow the medical prescriptions and advice. However, medical doctors pointed out that, if a PwP is not doing well, visualizing a poor health state might have the contrary effect.

Therefore, the choice was to present simple data gathered by the system, which PwP usually try to collect in order to show to their physician. The features to be shown in this application were: ON/OFF periods, FOG, dyskinesia, festination and falls. Along with this, the visualization tool would also show *failed medication intakes*, rather than all data about medication. The final result may be seen in Figure 6.6.



Figure 6.6 Screenshot of the 'My Day' app.

- **On the Appointments.** The idea brought forth about warning the user whenever he or she was setting up an appointment which most likely overlapped an OFF phase was not popular. After some initial discussion, participants agreed this might be dangerous not only because – given the several variables involved – it is quite difficult to predict an OFF timeframe, but also because having this information beforehand could most likely create unnecessary anxiety.
- **On the ACS icon.** Participants decided the best icon to convey the idea of auditory cueing between some elaborated and proposed ideas.

Despite the effort placed onto adopting inclusive design for UI design, the users' concerns about the response of the touch screen led to conduct more research into the touch patterns of PwP in order to try to define what characterizes an intentional tap, and thus optimize interaction with the smartphone by reducing error. For the purpose, a specific test was designed and carried out with 4 participants with PD.

The tests were designed to explore the possibility of creating an algorithm to differentiate voluntary from involuntary taps using the touch data provided by the Android API. For that a little game was designed to persuade PwP to do voluntary taps on the smartphone's screen, consisting in basic math operations where the user had to answer a question by tapping one of 3 possible answers (Figure 6.7a). This game allowed to easily observe when a person would intentionally tap an option or tap on another part of the screen by chance.

It was planned to achieve at least 11 voluntary taps per participant, in this way 11 questions were presented and if they failed solving the problem at

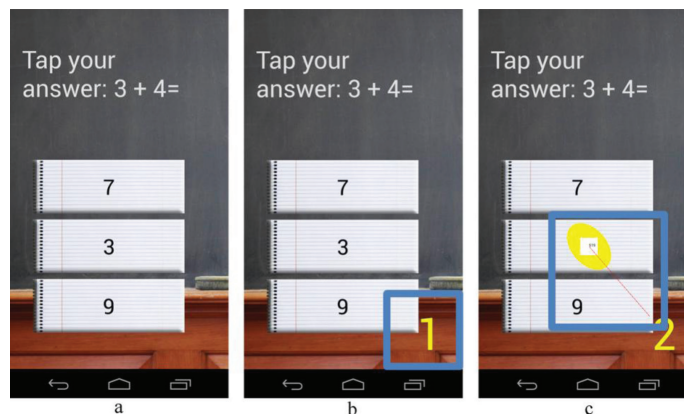


Figure 6.7 a) Initial screen; b) Number indicating the tap counting; c) Custom display of a tap event.

the first time they would need at least one more tap to get the next question. However, we could not induce any involuntary taps from the participants; therefore, no minimum number of involuntary taps per participant was set. The tests were recorded on video and each tap would increment a number on the screen (Figure 6.7b), so after the test was done it was possible to discriminate if a tap was voluntary or not.

The data provided by the Android API consisted of tap time, area of touch, pressure of touch and dislocation of the finger during the tap event which could be used to both perceive the orientation of the finger. The area of touch and pressure were only estimated by the Android API by measuring the change in capacitance on the screen, therefore not corresponding to real measures. As a result, a visual representation on the screen of these measures was created, as a means to test their correspondence to real measures. The pressure was represented by an ellipse that we then stretched and rotated accordingly the perceived orientation of the tap event, the area by a square and the orientation by a red line (Figure 6.7c).

Despite inconclusive, the results suggested that there should be room for improvement and that this analysis should be pursued further in the future. An interesting correlation between the contact time in voluntary and involuntary taps was found. However, the pressure and area had little fluctuations; the direction of tap also did not prove effective because PwP lacked a consistent movement that was necessary to detect correctly the orientation of the tap gesture. But nevertheless, the information about the dislocation of the finger could be used to mark involuntary taps if the finger moves too far away from the first point of touch. Hence, the most probable outcome of future tests will be a time-distance frame where a voluntary tap is considered as a tap that respects that time-distance frame, and involuntary tap as one that does not respect that time frame. This timeframe would be necessarily adjusted by the user in order to better suit his/her needs.

Following these very concerns in optimizing interaction and preventing errors, the velocity of scroll was adapted in order to better control for the presence of dyskinesia. Furthermore, it was added the option to replace the scroll gesture by tap buttons with upward and downward (Figure 6.8).

6.5 Final Usability Tests

For the purpose of conducting comprehensive usability tests with PwP, participants were recruited through Hospital de São João, in Oporto (Portugal). The documentation was sent to the Ethics Committee and approval was obtained in due time upon documentation submission.

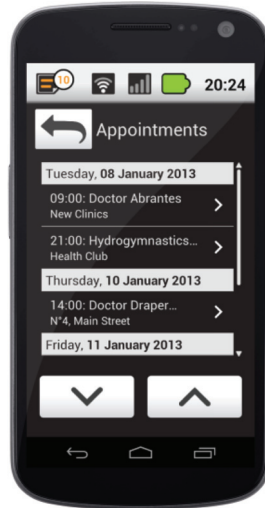


Figure 6.8 Arrow buttons as an alternative to the scroll gesture.

6.5.1 Research Questions

The main questions left unanswered were related to touch interaction, ease of navigation and the affordances of particular patterns. Regarding navigation, most questions were brought about by the two most complex applications: Medication and Appointments. These, it was supposed, will be frequently used and imply an array of activities and tasks which might be difficult to handle, such as interacting with reminders, introducing new data, browsing and searching for specific data, amongst others. Therefore, usability tests focused on evaluating the ease of understanding of the navigation experience, while, assessing the touch and gesture interactions on the background.

6.5.2 Sample

The sample was recruited from the neurology department, a group of a physiotherapist's patients and a day care centre. No exclusion criteria were set, except for the presence of concomitant health conditions which caused motor or cognitive impairments beyond those owing to PD. A total of 12 participants were recruited, although three were excluded for not being able to finish the usability tests due to poor mental state. Consequently, the sample was reduced to nine participants, which resulted on five tests for Appointments, five tests for Medication and four tests for scroll accessibility. The sample had an average

age of 71.3 years old, \pm STD 10.4, (median: 73) and participants had had PD for an average of 9 \pm STD 8.6 years (median: 6).

6.5.3 Protocol, Script and Metrics

As there were many items in need of evaluation, there was the risk that usability sessions would be too lengthy and hard on participants. Therefore, the session was devised into two different session tests, one for each application: Medication and Appointments. In this way, beyond avoiding wearing out the participants, bias was also avoided to some extent, as participants would not learn visual and interaction patterns from one application to the next.

The protocol followed the usual steps in usability testing: researcher presentation, project presentation, material presentation, study presentation and goals, obtaining informed consent, session tasks and debrief.

The variables being measured were as follows: tap button precision, tap length time (evaluated with FUSAMI [14]), task completion, number of errors and scroll errors (measured afterwards through video observation and with the specific test). Additionally, in order to continue to adapt the sensibility of the screen to better fit PwP the touch data from the appointment tests was catalogued in voluntary taps and involuntary taps.

The scroll test was done at the end of the 'Appointments' session and it had a simple design, it consisted of a contact list with thrice the number of contacts supported by a screen with no need for scroll and the person had to tap on a contact which was only accessible through scrolling. For the 3 types of scroll all the names of the contacts changed, but in all of them the contact was in the last position of the second scrolling panel, thus being required to do an entire scroll to see it; scrolling all the way to the end of the list would hide the referred contact once more. The measures used were: number of touches on the screen and time to find the contact.

The test material, protocol and script were subjected to pilot testing with two participants with PD for each test, who were recruited through Fraunhofer's contacts with day-care centres and who signed the informed consents to take part in the pilot tests. After the pilot tests the session plan was refined.

6.5.4 Results

Some results obtained on the main issues addressed during the set of usability tests are discussed:

6.5.4.1 Appointment test

Using the calendar and reading an appointments list. Overall the participants recognized which days contained appointments (Figure 6.9), even though some had more difficulties than others. In the end, all participants identified the days correctly. Current day is also visually distinct from the remaining month days, but only one participant noticed this.

As expected, when asked to see more information about an appointment they had on a specific day, participants tried to press on that day, despite being too small for participants to accurately tap it. Participants were able to read the correct event. They only had difficulties when the event did not show immediately on the list and they had to scroll to get the correct appointment. When the facilitator scrolled to the right position they read it without effort.

Tapping on an appointment to see more details. In general, the participants were able to correctly identify the name of the appointments as a clickable element and tapped them without almost any problem (Figure 6.9).

Editing/creating an appointment. Here the participants had more difficulties to know what they had to do in order to edit an appointment (Figure 6.10). Creating a new appointment was the most complex task on the tests and the participants were only able to accomplish it with assistance. Generally, the editable elements were easy to identify, however when they were 'hidden' by the scroll, participants needed help to find them. Additionally, the pop-ups confused some participants. When the pop-ups of date and hour



Figure 6.9 Calendar screens: a) Calendar; b) Week list.

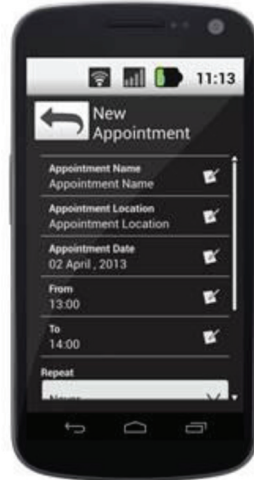


Figure 6.10 New/Edit appointment screen.

appeared on the screen some participants instinctively tried to tap on ‘Set’ before using the controls on the pop-up to set a different hour/date.

Using scroll. No participant, with the exception of the one who was used to touch technology, had the initiative to use scroll. After its use was shown to them, participants were able to replicate it in that situation but rarely used it afterwards. Even though they were able to do the gesture, they would only perceive the information currently displayed on the screen and would not seek more information. Participants did not notice the visual marking on the screen indicating the scroll.

6.5.4.2 Medication test

Reading the medication list. Almost all participants correctly identified the medication names and notes with almost no effort (see Figure 6.11).

Tapping on a medication to see more details. When asked to see more details, the majority of the participants correctly tapped on the medication to disclose more details about it, but they had difficulty in correctly reading the intake hours for that particular medication. As the intakes were on a different list from that of other elements, only after reading all the details regarding that medication (or getting some hints from the facilitator to seek more information), did they finally read the intakes; again, with difficulties.

Edit intake hour and frequency. After understating the concept of intake, it was easy for the participants to tap over the intake event to edit it. Concerning

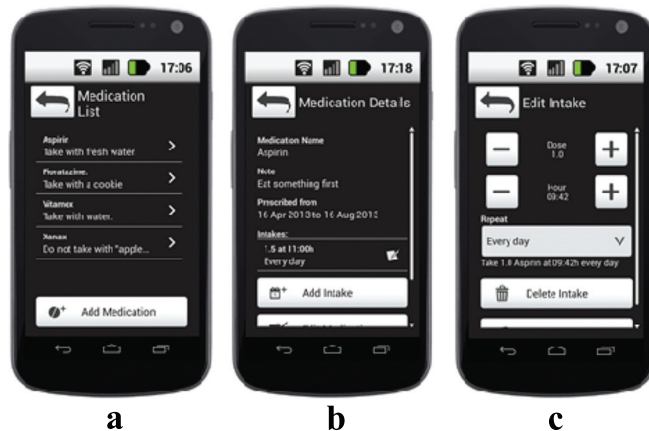


Figure 6.11 Medication apps screens: a) medication list; b) medication details; c) edit intake.

the editing mechanisms, and despite some initial confusion, participants were able to use them correctly. After some taps they understood what the ‘+’ and ‘-’ controllers were for and used them. Participants were also able to recognize the spinner to change the frequency of the intake, and choose the correct days although with hesitation on what the options: “Custom interval” and “Custom week days” would do. Again, they were not able to scroll down to tap the ‘Save’ button.

Read the medication schedule and list of missed intakes. Despite the majority of the participants having correctly identified the hours and medication which they had to take, some had difficulties associating the hours appearing on the list with the correct medicament. Generally, participants that understood the concept of missed intakes were able to say which medicaments were not taken.

Interact with the medication alerts. Overall, the participants understood clearly which medicaments they had to take, but some had difficulty understanding what they had to do in order to inform the system that they only had taken one medicament of the displaced list (Figure 6.12). However, with the help of the facilitator showing them how tapping on a medicament would mark it with a check icon, they would then proceed to tap over ‘Taken’ to finish the task.

Voluntary and involuntary taps differences. The test allowed us to observe differences in touching times between some involuntary and voluntary taps (Table 6.4), though many times those differences were not present, making it not possible to differentiate them in an automatic way. However, it is possible

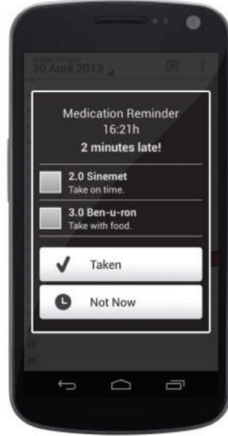


Figure 6.12 Notification pop-up screen (medication reminder).

Table 6.4 Mean duration of a single tap for each participant

Participant	Involuntary		Voluntary	
	Mean of Time (ms)	Std. Deviation of Time (ms)	Mean of Time (ms)	Std. Deviation of Time (ms)
1	166.62	197.38	133.19	90.64
2	355.00	295.57	373.06	250.11
3	322.78	481.36	241.67	217.59
4	413.53	456.89	193.50	87.46
5	703.25	281.18	292.92	178.22

to do it if the PwP intentionally changes his/her behaviour while touching the screen. Since most of the time the involuntary taps are quick (when one has tremor and just passes the finger over the screen, or low dexterity and notices that he/she is touching intentionally on the screen and moves the finger right away), a minimum time threshold could be settled to discard those taps and PwP would always have to press the button above that threshold to have a valid tap. Additionally, a maximum time threshold could be also settled for the case that the person is touching on the screen and does not notice it, thus also discarding this possibility of involuntary tapping.

6.6 Conclusions after the User-Centred Process

This section presents a list of some generic conclusions after the user-centred design approach process organized in the frame of REMPARK, giving, in this

way, the opportunity to generate a good solution for the interface implemented on the used Smartphone along the pilots:

- **Concerning the Screen Interaction:**

- There were no noticeable difficulties on the accuracy of the tapping action when buttons size was reduced (elements measuring 10,5 mm in height were tested).
- Concerning the test on the best approach to scrollable screens speed (normal or reduced), participants were able to use both. There were no enough data to conclude something relevant.
- When participants were using button arrows as an alternative to scroll gestures, they were able to learn and subsequently use the arrows approach. In principle, it was noticed that it was not intuitive for them.
- It is not possible to discriminate voluntary taps from involuntary ones although it might be possible to induce new tap behaviour to PwP in order to make that distinction possible.
- In general, the users had no problems using spinners either on the Medication or the Appointments applications under test.
- Concerning the action produced when clicking on “+ and -” buttons, some users had difficulties using them at first, but after some time or after getting some hints, they got used to them and were able to finish the tasks using these.
- Participants were able to use the pop-up dialogues to change date and time. Some were confused at first and used the down arrows to increment the values instead of the up arrows; but then quickly learned from the mistake.
- No user had problems tapping over the checkboxes.

- **Concerning the Medication:**

- In general, the participants were able to read the medication list and details. The main difficulty was in reading the intakes list for a given medicament.
- The most part of participants had no problems reading the medication that they supposedly had to take for the current day.
- After some hesitation on the options ‘Custom interval’ and ‘Custom week days’, users were able to understand the intake repetition options.
- Most participants were able to identify the medication that they had missed.

- After some interaction with the researchers, users were able to understand that they can modify a missed intake by inputting the real intake hour.
- **Concerning the Appointments:**
 - Participants were able to read correctly which days had appointments, although they missed the current week and the current day markings.
 - It was difficult to understand the tree view of Month > Week > Day. Nevertheless, they were able to use the calendar and read the appointments for a specific day.
 - Overall participants were able to correctly read the date of the events presented on a list, although there were some exceptions.
 - Users were able to understand that an event can be repeated multiple times on the calendar by editing it.
 - When users tried to add a new appointment, they needed help to type on the phone, and scroll down to see more options and the save button.
 - In general, it was difficult to use and to add alarms to an event.

6.7 Characteristics of REMPARK Smartphone Applications

Considering all the previous presented user-centred process and the preliminary conclusions obtained, a final implementation of the smartphone applications and user interface was organized according with the following main ideas:

- **On Home Screen**

In order to avoid scroll and allow users to have a quick overview of each block of applications, the home screen was divided into three main blocks: General applications, Favourites and REMPARK applications.
- **On Medication**

The Medication application retrieves and displays the neurologist prescriptions. At the same time it allows the user to add other medication which is not Parkinson's-related. Users can edit this latter medication, but not the one which has been placed into the system by the medical doctor.

The application shows the list of current medications the user is on, missed intakes, a schedule of intakes and a record of intakes.

The application shows medication reminders at intake time and the user may choose to keep track of his intakes. In this case, the medication reminder displays an option reading 'Taken'. The option for the wording was to prompt users to press the option 'Taken' only after they have taken the medication. This was done to provide users with a mechanism to help them know whether or not they have taken the medication. If, by some chance, the user has taken the medication but forgot to record the event on the smartphone, he or she can go to the 'Missed Intakes' list and edit it by choosing that particular missed intake and editing it by inserting the hour at which the medication was indeed taken.

- **On Appointments**

As with the Medication application, this application retrieves the information from the REMPARK server on existing appointments made by the doctor, while allowing the user to add their own. Again, users are only allowed to edit the information which has been inputted through the smartphone itself.

The Appointments application allows the users to access a calendar view (and reach their appointments from there), shows a list of events ordered by date and allows the user to create new events from the main menu.

- **On Auditory Cueing System Controller**

The auditory cueing system controller application has a single screen and allows the following basic options: turn on/off, change volume and change rhythm. Users may also choose to change the sound type by previewing and selecting it and predefine the settings for the auditory cueing. This is done through the settings application.

- **On Medical Questionnaires**

Medical questionnaires pop-up as they are fed into the system. Nevertheless, the user may opt to dismiss the questionnaire and answer it later. In this case, the Questionnaires application icon displays a notification showing the number of questionnaires waiting to be completed.

Due to the limited available space in a single screen (i.e. without scroll), there will be limits imposed to the number of characters for questions and answers. The reasoning behind this choice lays in the fact that the smartphone is one of the possible ways to answer medical questionnaires. The use cases predict that more complex or longer questionnaires may be answered through the web interface.

- **On My Data**

The My Data application is meant for emergencies or for a quick overview of the user's health data to display, for instance, in a visit to the doctor who is not part of the REMPARK system. After a pop-up with a warning about the person's disease (meant for emergency scenarios), it shows the smartphone owner's picture, his or her name and phone number, along with health information: blood type, medication list, concomitant illnesses and specific data about Parkinson's disease.

- **On My Day**

The My Day application refers to what was at first called 'Disease Status' application. The name was changed to a more user friendly working. It has a single screen displaying information of the user's state over the previous day: ON/OFF periods, FOGs, festination episodes, missed medication intakes, falls and dyskinesia.

- **On Quick Emergency Call**

This application works as a quick dial to an emergency number and is displayed both at the Applications and Favourites screens.

- **On Calls**

The Calls application allows the user to make a phone call through a list of contacts or by typing in the number using an extra-large dial pad. It also allows checking missed calls and call history.

- **On Contacts**

This application displays a regular contacts list and allows the user to define favourite contacts, call or send a message to a given contact, add new contacts and delete existing contacts.

- **On Messages**

This application allows the users to simply read, listen to and send messages (through text or speech). It also supports sending and receiving pictures.

- **On Settings**

The Settings application allows the user to set his or her preferences regarding Sounds, Vibration, Wi-Fi, Accessibility, Language, Auditory Cueing Settings, to set a Caregiver (which will show at the Favourites home screen and to Add a new device. In order to allow for troubleshooting, this menu shows an option which allows users to check the status of the sensors and actuators in the REMPARK system.

- **On Status Bar, Notifications and Shortcuts**

The status bar is shown at the top of all screens and it displays information about the time, the battery status, the Wi-Fi connection status and strength

of cellular signal. Furthermore, the status bar is used to host shortcuts for cueing controllers and to provide users with straightforward information about their status. When ACS cueing icons is on display in the status bar, they act as buttons to the applications. The notifications pertaining to each application will be shown on the home screens, on top of the corresponding application icon.

6.8 Some Concluding Remarks

The presented interface was completely integrated in the smartphone and used as part of the whole REMPARK system during the complete trials organized as one of the main activities at the end of the project. Participants were given the smartphone along with a user manual and, in the end, were asked to fill in SUS (System Usability Scale) and QUEST 2.0 (Quebec User Evaluation of Satisfaction with assistive Technology) questionnaires. Therefore, participants evaluated the whole system, not just the smartphone user interfaces.

The results indicate that there are some issues in terms of learnability, which should be looked at in the future. As it was reported during evaluation of REMPARK, “. . . *managing all that REMPARK has to offer at once can be quite overwhelming, especially if one is using the system for a short period of time and if the user’s level of familiarity with technology is not very high. REMPARK is a completely new and innovative system and it is only natural that these barriers emerge. In the future, however, we could try to work on this part of introducing the system to new users, covering the unboxing experience as well. But this is for the future, as it was never part of the goals for our project*”.

It should also be noted that each participant interacted with the system for four days, which could explain why, at the end of the trials, participants were not completely familiarised with all the REMPARK apps. Nevertheless, satisfaction levels, as reported in the scales used, were quite high – for the participants, the REMPARK system was comfortable, secure and safe.

Finally, one of the most interesting found discoveries during the field trials had to do with the ‘My Day’ application. The app was not planned at first and was born from listening to PwP’s conversations about their symptoms. During the field trials, screen interaction was analysed. The ‘My Day’ screen showed a high activity with taps on the date and on the elements related to symptoms. This seems to suggest that participants wanted to interact with their own data.

On REMPARK's final workshop, we had the opportunity of showing the apps to Sara Riggare, a PD advocate and PwP herself. We commented on these results and findings, which did not surprise her. However, she recommended to focus on displaying the positive events, rather than the negative ones. Further work on the 'My Day' app following the field trials and the experts' advice was considered by us to be relevant work for the future

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- [14] FUSAMI is a web platform developed by Fraunhofer AICOS to perform analytics on user interaction, by collecting data on this interaction and analysing it with analytical algorithms.