Smartphone Exercise Applications For People With Parkinson's Disease

Danial Afzaal

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Preface

The project “Smartphone Exercise Applications For People With Parkinson’s Disease” helped enhance my knowledge regarding mobile health (mHealth) applications, and the importance of technology in health related issues. From January 2021 to May 2021, I devoted my time to researching, writing and developing smartphone applications to help manage symptoms of Parkinson’s Disease.

First and foremost, I would like to thank professor Weiqin Chen, for being a wonderful supervisor and guiding me throughout the project. I would also like to thank fellow students for keeping me motivated throughout the project.

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Abstract

Parkinson's Disease (PD) is the second most common neurodegenerative disease, affecting more than 10 million people worldwide. It is a progressive disease that includes both neurological and motor symptoms. Research has shown that physical therapy and exercise can be valuable tools in managing the symptoms of the disease and in deceleration of the severity. However, the symptoms together with limited access to neurorehabilitation facilities, and physiotherapists, mean that commitment to exercise is a demanding task for people with Parkinson's Disease. In this master project a smartphone application that allows the creation of personalized workout routines, guides, and motivates the patients was developed to address this issue and improve exercise adherence. The symptoms of PD can result in deterioration of psychomotor abilities and poor manual dexterity. To ensure that the impediments experienced by people with PD when interacting with touchscreens were accommodated, the design followed specialized guidelines and recommendations for people with PD discovered in the literature review. The applications were then further evaluated based on accessibility testing software and also manual evaluation based on the principles of universal design. This study did not include user testing, therefore further work is recommended to observe changes in exercise adherence over a longer period of time.

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1 Introduction

Parkinson’s Disease (PD) is at present the second most frequent neurodegenerative disorder, after Alzheimer disease (Wirdefeldt, Adami, Cole, Trichopoulos, & Mandel, 2011). The disorder predominately affects elderly people. It is estimated that the number of People with Parkinson’s Disease (PwPD) world-wide is 10 million, and only 4% of all cases reported are before the age of 50 (Emily Downward, 2019). Reports from the European Parkinson's Disease Association project that PwPD over the age of 50 will be between 8.7 million to 9.3 million by 2030 (Dorsey et al., 2007).

PD is a disabling condition characterized by a wide spectrum of both motor and non-motor symptoms, inducing progressive disability at the more advanced phases of the disorder (Chaudhuri, Healy, & Schapira, 2006). The non-motor symptoms include psychiatric and dysautonomia symptoms such as anxiety, depression, hypotension, difficulties in focusing and unintelligible speech. There are four cardinal motor symptoms: bradykinesia (slowness of movement), muscle rigidity, tremor, and postural instability (Wirdefeldt et al., 2011).

Along with pharmacological and surgical treatments, conventional physical therapy and exercises have proven to be effective approaches in alleviating the symptoms (Speelman et al., 2011) (Tomlinson et al., 2013). The studies demonstrate that exercise considerably improved quality of life, functional mobility, balance and gait velocity. Over the last decade, exercise has been recognized as an important constituent in managing the severity of PD. However, participation in neurorehabilitation and physical therapy can be a demanding task for some patients due to therapist availability, cost of treatment, access to facilities, and lack of motivation. A cost effective and highly accessible solution is smart phone applications.

There has been a prodigious growth in the use of information technology in healthcare. By means of Information technology the positions of patients can be greatly enhanced, by providing relevant medical information and access to medical records (Berg, 2004). Simultaneously there has been a similar growth in quotidian use of internet in elderly people in developed countries. Majority of these use smartphones with touch screen based interfaces to access the internet. (Levy-Tzedek, Krebs, Shils, Apetauerova, & Arle, 2007) reports that 69% of elderly people have their own mobile phones.

1. Goal of the Project

Exercise can be a strenuous task for PwPD, however factors, such as low-self efficacy, poor outcome expectation, lack of real-time feedback have been revealed as stronger attributing factors to non-exercise adherence than disease severity (Ellis et al., 2013). Self-management, increased participation, collaborative goal setting and treatment planning have shown to combat this, and increase exercise compliance (Lakshminarayana et al., 2017).
The benefits of physical exercise combined with the mass adoption of smartphones in elderly, envisages a smart phone based exercise application designed for PwPD.

Furthermore, some symptoms of PD such as deteriorated manual dexterity has an obvious impact on the use of touchscreen based devices. Research on application development especially aimed at PwPD is limited, however there are a few existing design guidelines. Therefore the primary objective of this project is to develop an exercise application for PwPD that guides, motivates, and tracks exercise in a collaborative manner with healthcare professionals, according to design guidelines and recommendations found in the literature review.

1.1 Organization of thesis

Section 2 contains an extensive literature review on development of applications for PwPD and elderly people. Furthermore specific symptoms of PD, that creates barriers for touchscreen interaction is investigated. Lastly design guidelines and recommendations for both PwPD and elderly found in previous literature is exhibited. In section 3 the methodology for designing and developing the applications are described. Section 4 includes the result of the developed applications, and accessibility testing. Section 5 covers the discussion the result and also future work, lastly the conclusion is presented in section 0.

2 Literature Review

2.1 Literature Review Methodology

In this section there will be done reviews on literature that is relevant for the development of the application. The review will help examine the current state-of-art of mobile applications for PwPD. Moreover the literature review will help discover guidelines and recommendations that ensure a high level of usability and accessibility for the target group. PD usually affects people aged 50 and over, ergo literature related to development of application for elderly people is also reviewed. Guidelines and design principles from those literatures is also included.

2.1.1 Criteria for article and database selection

To ensure that the literature was relevant to the project, search terms and inclusion criteria were defined. The search for literature was conducted on various online databases and libraries like, IEEE Xplore, OsloMet Oria, Springer, Research gate, ACM Digital Library and Google Scholar, with the following search keywords: Parkinson's disease, shaking, tremor, app, touchscreen, elderly, smartphone, exercise, touchscreen guidelines, aging, and gestures.

Ideally I wanted results from 2017 and later, however there was limited research, thus the time frame got extended to results from when smartphones were first introduced i.e. 1992 to 2020. Touchscreen now versus then has changed drastically, however some of the discovered barriers may still be applicable, therefore results from 1992 and later is still viable.

The results of the search were then evaluated based on the following inclusion criteria:

- The paper is published between 1992 and 2020
- Must include the use of touch based devices
- Must cover design and development for people with PD or equivalent symptoms
- The paper is in English

- Must be peer reviewed

2.1.2 Overview of selected literature

Table 2-1 - Overview of selected literature

Date	Title	Authors	Keywords	Methodology	Research Aim	Conclusion
2013	Touch Screen Performance by Individuals With and Without Motor Control Disabilities	Chen, Savage, Chourasia, Wiegmann	Touchscreen, Performance, Disability	User study of a total of 53 users. 38 with a motor control disability, and the remaining 15 with no motor disability.	Investigate the effects of button and gap sizes on performance by people with varied motor abilities.	Results indicate a decrease in miss touches, errors, and time to complete task by elderly and disabled people when button sizes were increased.
2013	Physical Accessibility of Touchscreen Smartphones	Trewin, Swart, Pettick	Motor impairment, mobile devices, touch-screen interaction, accessibility	Interview and observation of 16 participants, whose mean age was 40. The participants represented varied physical abilities. Such as restricted range of motion, isolation of muscles, and coordination	Examine the physical access of touchscreen smartphones.	Participants found using touch-screen devices physically easy. However they felt it was more visually straining. Tablets performed better than smartphones, mainly because of the size difference.
2018	Confronting Common Assumptions About the Psychomotor Abilities of Older Adults Interacting with Touchscreens	Joshi	Older adults, Touchscreens, psychomotor abilities, performance enabling technology	User evaluation and self-assessment involving 49 older adults, whose mean age was 81 years. The performance was assessed during task solving on touch based interface.	Examine and confront commonly made assumptions about older adults capability when interacting with touch based technology.	The older adults were unable to maintain a measured performance score at the average level of a control group with median age of 40 years. The difference in self-assessment and actual performance

Date	Title	Authors	Keywords	Methodology	Research Aim	Conclusion
						was lower amongst the older adults. Meaning the older adults were better at assessing their actual performance.
2011	Elderly User Evaluation of Mobile Touchscreen Interactions	Kobayashi, Hiyama, Miura, Asakawa, Hirose, Ifukube	Smartphones, Touchscreens, Gestures, Aging, Senior Citizen	Observational evaluations, and performance measurements of 20 elderly participants. Tasks included performing basic gestures such as taps, drags, and pinch.	Assess standard mobile touchscreen interfaces for the elderly.	Results show that mobile touchscreens were generally easy for the elderly to use, also there was improved proficiency in dragging and pinching motions, after one week of experience.
2019	Cluster Touch: Improving Touch Accuracy on Smartphones for People with Motor and Situational Impairments	Mott, Wobbrock	Touchscreen, human centered computing, accessibility,	User study with 24 participants, 12 with motor impairments and 12 without.	Present a user model that improves the accuracy of touch input on smartphones for people with motor impairments, and situational impairments.	The model improved touch accuracy by 14.65% for people with motor impairments, and by 6.81% for people without motor impairments, but who were walking.
2014	Motor-impaired touchscreen interactions in the wild	Montague, Nicolau, Hanson	Interaction devices, Touch screens, tremor	A 4 week study with 9 participants using a mobile touchscreen device. A Sudoku stimulus application measured the interaction performance.	To measure and understand the variance of touchscreen interaction performances by people with motor-impairments.	Results indicate a high level of interaction performance variance between users. And also between device sessions.

Date	Title	Authors	Keywords	Methodology	Research Aim	Conclusion
2021	Impaired Touchscreen Skills in Parkinson's Disease and Effects of Medication	Vleeschhauwer, Broeder, Janssens, Heremans, Nieuwboer, Nackaerts	Parkinson's disease, touchscreen skills, dopaminergic medication, upper limb	12 PD patients, off and on medication, and 12 healthy controls, were asked to perform various touch gestures, such as tapping, single and multi-direction sliding.	Investigate the impact of PD and anti-parkinsonian medication on touchscreen usability.	PD patients face barriers and issues when using touchscreens, even when optimally medicated. This is especially prevalent when performing more complex gestures such as multi-direction sliding.
2012	Elderly text-entry performance on touchscreens	Nicolau, Jorge	Elderly, touchscreen, text input	15 elderly participants were asked to enter a text, on two different devices (mobile and tablet). Speed and accuracy was measured on both devices.	Inform future design of touchscreen keyboards for elderly people.	Results show higher error rates compared to younger users. Most common types of errors were omissions (10.8%), substitutions (5.8%), and insertion (4.6%). Hand tremor strongly correlated to input errors.
2019	Evaluation of Touch Technology for the Aging Population	Gabyzon, Chiari, Laufer, Corzani, Danial-Saad	Senior citizens, Tools, Task analysis, Aging, Statistics, Usability	A software application was developed that assesses touchscreen performance. Two user groups, 12 middle aged users (over 45 years) and 16 users over 75 years, were assessed by using the software.	To provide evidence for The Touchscreen Assessment Tool (TATOO) to become a prevalent tool for clinical professionals treating elderly.	The elderly individuals demonstrated less accurate and considerably longer temporal measures (reaction and duration times).

Date	Title	Authors	Keywords	Methodology	Research Aim	Conclusion
2020	Retention of touchscreen skills is compromised in Parkinson's Disease	Nackaerts, Ginis, Heremans, Swinnen, Vandenberghe, Nieuwboer	Parkinson's disease, Motor, learning, Upper limb Retention Transfer	11 PD patients and 10 healthy participants were tested, by performing a Swipe-Slide Pattern task on a touchscreen device resembling a smartphone.	Investigate the impact of PD on retention of motor skill related to manipulating touchscreens.	PD Patients performed worse on the mobile phone task compared to healthy elderly.
2016	User Interface design guidelines for smartphone applications for people with Parkinson's Disease	Nunes, Silva, Cevada, Barros, Teixeira	Touchscreen accessibility, user interface design, usability guidelines, smartphones, touch gestures, motor impairment, Parkinson's disease	Usability experiments with 39 PD patients. Interview of healthcare professionals, extensive review of previous literature.	To determine how to better design smartphone user interface for people with Parkinson's Disease	Documented list of PD symptoms that affect interaction with smartphones. Developed 12 user interface guidelines for people with Parkinson's disease.
2012	Touch-Based Mobile Phone Interface Guidelines and Design Recommendations for Elderly People: A Survey of the Literature	Al-Khalifa, Aljami, Mona, Al-Razgan	Elderly people, Mobile phones, Accessibility, Design Recommendations, Guidelines	Comprehensive literature review.	Present guidelines that will help designers and developers to develop touch based mobile interfaces for elderly people.	A list of design recommendations for older adults based on extensive literature review.
2017	Using a smartphone-based self-management platform to support medication adherence and clinical	Lakshminarayana, Wang, Burn, Chaudhuri, Galtrey, Guzman, Hellman, James,	Parkinson's disease, smartphones, medication adherence,	16 week trial of a Parkinson's tracker app.	Investigate if smartphone-based application can improve medication adherence.	Patients using the app reported considerably improved adherence in medication.

Date	Title	Authors	Keywords	Methodology	Research Aim	Conclusion
	consultation in Parkinson's disease	Pal, Stamford, Steiger, Scott, Teo, Barker, van der Eijk, Rochester, Williams				
2015	Design of the Park-in-Shape study: a phase II double blind randomized controlled trial evaluating the effects of exercise on motor and non-motor symptoms in Parkinson's disease	Van der Kolk, Overeem, de Vries, Kessels, Donders, Brouwer, Berg, Post, Bloem	Exercise, Parkinson's disease, non- motor symptoms, application	User study with 130 patients. Two groups one for aerobic exercises, and one for non-aerobic exercise. Both groups are supported by motivational smartphone application.	Evaluate if aerobic exercise clinically improves motor symptoms in sedentary PD patients.	Development of the application with gamification elements significantly increased motivation in users.
2016	The mPower study, Parkinson disease mobile data collected using ResearchKit	Bot, Suver, Neto, Kellen	PD, mobile application, exercise, design, movement disorder	Observational study conducted through an iOS application interface.	Help people with PD monitor symptoms, and improve quality of life	Developed iPhone application.

2.2 Symptoms of Parkinson Disease

Investigating the specific symptoms of PD, and experienced deficits when interacting with a touchscreen, will help inform the design, and ensure a high level of usability.

PD has a wide spectrum of motor and non-motor symptoms. Cognitive symptoms can include slowness of thinking, unintelligible speech, declining visual perception, and concentration difficulties (Rafiq, Hussain, Nadeem Faisal, & Mirza, 2019). Although these symptoms have an impact on the user experience, they are not as detrimental as motor symptoms, since the main input from user is via touch. Therefore the main focus of the literature review is on the motor symptoms. These symptoms include: Hypokinesia which is reduction of spontaneous motor activity, Bradykinesia and Dyskinesia which are varieties of spontaneous motor activity. The most commonly found symptom is tremor. This movement disorder causes recurrent slow tremor of the hands at rest. The tremoring is intermittent, it can be at amenable level or even disappear, when voluntary movement is performed (Biloborodova et al., 2019).

2.3 Touchscreen Interaction for both PwPD and elderly

The rise of touch screen based interfaces and devices has made manual dexterity a vital skill when interacting with technology today. However, the ability to use smartphones in PD patients is often assumed (Espay et al., 2019). Deterioration in fine motor skills and tremor challenges can temperately impede interaction with touch screens (McNaney et al., 2014). This is supported by (Nicolau & Jorge, 2012) they tested the ability of fifteen participants with various level of tremor, to write using touchscreen keyboards. Their results showcase a higher level of selection error for people with tremor compared to people without. Furthermore, (Montague, Nicolau, & Hanson, 2014) reported a 15% increase in erroneous target selection when evaluating five out of nine people with PD. It is worth noting that both researches include participants in different stages of PD, the severity of disease has an obvious impact on the level of interaction deficiency as also observed by (Nackaerts et al., 2020).

Although it is possible to be diagnosed with PD at a younger age, the disease is far more prevalent at older ages. Accordingly reviewing literature about older adults interaction with touchscreens is also germane. There are a lot of shared challenges between people with PD and older adults. For instance, they both experience some level of impairment in their fine motor movements, and dexterity (Smith, Sharit, & Czaja, 1999). These impairments present several challenges, (Elboim-Gabyzon, Weiss, & Danial-Saad, 2021) with touchscreen devices. Most of the challenges being related to tasks requiring, precision, speed and or positioning. Another study by (Elboim-Gabyzon, Chiari, Laufer, Corzani, & Danial-Saad, 2019), assessed older adults touchscreen performance using Touchscreen Assessment Tool (TATOO). In their results the elderly individuals displayed less accurate and significantly longer reaction and duration times. There are plenty studies highlighting the effects motor impairments have on touchscreen interaction (Kobayashi et al., 2011; Nackaerts et al., 2020; van der Kolk et al., 2015). There is compliance in the results of these studies, motor impairments and old age can considerably hinder touchscreen interaction. However, despite the impairment, there are many opportunities to use touchscreens at a proficient level. Research done in (Joshi, 2018) suggests that allowing altering of the interaction based on the capabilities of the individual will improve proficiency, one way to adjust this interaction is by for example, using motion sensor data as presented in (Nicolau & Jorge, 2012). This solution allowed for greater accuracy and decreased interaction time for people with tremor. (Nunes, Silva, Cevada, Correia Barros, & Teixeira, 2016) showcases that a high proficiency level can also be obtained by simply having a sympathetic design of the user interface.

2.4 Current State-of-art exercise application for PwPD

There are hundreds of applications related to PD, on both Google Play Store[1], and Apple Store[2]. However most of them are low-level applications with a low user rating, whereas most of the higher-level application are only available through purchase. Therefore applications that was developed in studies were favored. These application

[1] https://developer.android.com/distribute/google-play
[2] https://developer.apple.com/app-store/

also provide greater explanations behind design choices and results on their efficacy can also be found in the studies.

2.4.1 The Parkinson's tracker app

The application was used and developed in (Lakshminarayana et al., 2017) to evaluate the effect of a smartphone application in promotion of patient self-management, treatment adherence and quality of clinical consultation.

The application included the following five features:

1. A sliding petal interface to track and score self-monitoring measures, such as exercise, sleep, mood, diet, movement, and suppleness. In the event that the petal interface was inaccessible, a zoom function to magnify the screen was incorporated (Figure 2-1).
2. A reminder system, that allows users to set up alerts and notifications to help track medication.
3. An option to generate a report of the data entered by the patient over a 3 month period (Figure 2-1).
4. Gamification of tasks that monitor physical responsiveness and cognition.
5. Information page about Parkinson's Disease

*Figure 2-1. **Left**: The pedal interface. **Right**: The interface for the generated report (Lakshminarayana et al., 2017).*

Participants who used the application in the study, were asked to set up medication reminders and utilize the app once a day, or at least on alternate days over 3 months. The participants reported significantly higher medication adherence after the 3 month trial period. Additionally the results report a high level of user retention. The study attributes factors such as simplicity and design of the user interface to being the reason behind the high user retention.

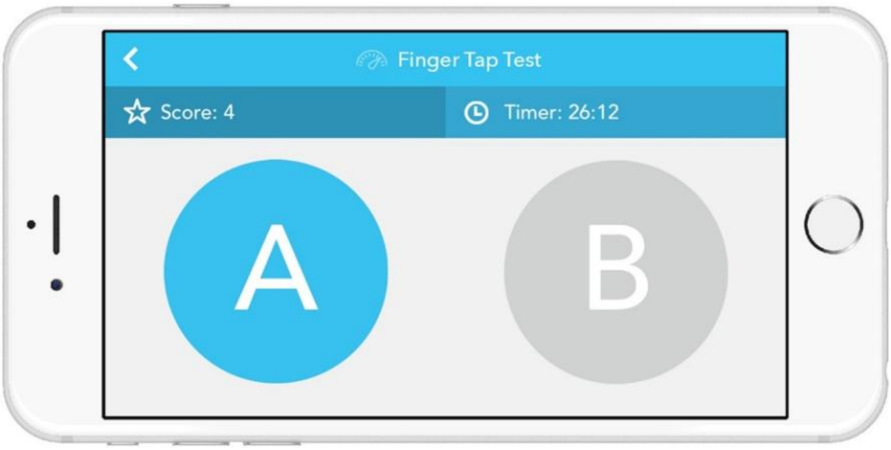


Figure 2-2. Finger tapping test on the Parkinson Tracker App (Lakshminarayana et al., 2017).

2.4.2 mPower

Launched in 2015 by the University of Rochester, the Parkinson mPower is a smartphone application available on iOS. It was developed and used in a clinical study (Bot et al., 2016). The app uses the iPhones sensors to track the patients symptoms such as tremor, balance and gait through activities. The app included four activities, referred to as “memory”, “tapping”, “voice”, and “walking”. Patients were asked to complete each activity at three separate times during the day, namely before taking medication, after medication, and lastly at some other time.

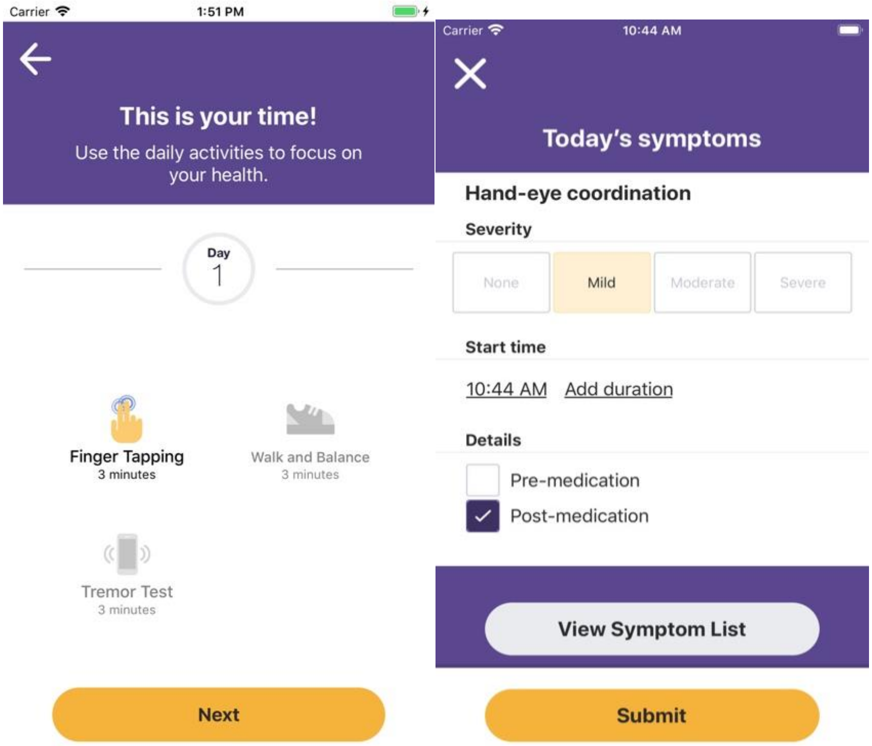


*Figure 2-3. The mPower Application. **Left**: Main interface. **Right**: Interface of the symptom submission feature (Bot et al., 2016).*

2.4.3 Park-In-Shape

Presented in (van der Kolk et al., 2015) Park-In-Shape is a tablet-based motivational app. The application shows exercises, goals and provides feedback and support about the performance. The application also includes a social aspect, where patients can view each other's results, cheer and compliment on performance. The exercises are explained through text and videos, and at least every 4 weeks the workout plan is evaluated, and if deemed too easy for a patient, a new set of exercises are presented. Training data is automatically saved after each session and uploaded to a server, where the coach or physicians can track the progress, and provide feedback and or incentives through an integrated reward system.

2.5 Guidelines and design recommendations for PwPD

In this section I will review literature that specifically addresses design principles and guidelines that improve accessibility for PwPD and or similar symptoms.

2.5.1 Cluster touch

(Mott & Wobbrock, 2019) present a combined user-independent and user-specific touch offset model named Cluster Touch. The model enhances touch input accuracy on smartphones for people with motor impairments or for people experiencing situational impairments such as walking while using their smartphone. Cluster touch acquires touch examples from multiple users to learn touch behaviors across the screen and to create a shared user-independent model. Then to make the model user-specific, touch samples from an individual user is collected and combined with the user-independent model. The users touch is calibrated by providing 20 touch examples. The user-specific model allows for more accurate corrections of touch offsets generated by a specific individual user. The results show that Cluster Touch improved touch accuracy by 14.65% for people with motor impairment and by 6.81% for people without motor impairments but who were walking.

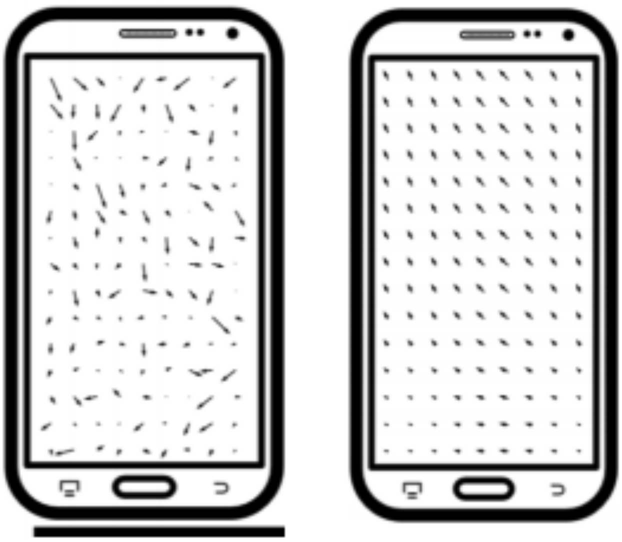


*Figure 2-4. **Left**: Touch examples from individuals. **Right**: Touch examples combined with user independent model, creates the user-specific touch model (Mott & Wobbrock, 2019)*

2.5.2 Recommended Button and Gap Sizes

(Chen, Savage, Chourasia, Wiegmann, & Sesto, 2013) investigated how button and gap sizes affected the performance of people with varying level of motor abilities. Participants in the study were presented ten combinations of five different button sizes: 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm square and two different gap sizes 1 mm or 3 mm. The button size and spacing combinations were randomized. Errors were defined as a touch that activated the wrong button, and misses were defined as a touch that landed outside of the intended area and did not result in button activation. Results from the study showcase:

- Disabled group averaged 2.9 times more errors than the non-disabled group.
    - Errors decreased by 59% as button size increased from smallest to largest.
- The disabled group averaged 3.9 times more misses compared to the non-disabled group.
    - Misses decreased by 84% as button size increased from smallest (10mm) to largest (30mm).
    - 22% more misses occurred at fap size 3mm than 1mm.
- The disabled group used on average 2.2 times longer to execute a task where participants had to accurately enter a four-digit number.
    - A 14% decrease in time consumption was observed as button size increased from the smallest to the largest.

The results indicate a decrease in errors, misses and time consumption as button size increased. The non-disabled group's performance phased at button size 20mm. While the disabled group showed improved performance up until the largest button size 30mm. Lastly no significant difference in performance was observed apropos gap sizes.

These results would insinuate that a button size of 30mm should be the intended and optimal size for the prototype. However, there a few things to consider, most prominent being varying display sizes. The results are generated from an experiment where the instrumentation device was a kiosk-type monitor with a display size of 15 inches. Whereas the design of the application in this thesis is intended for smartphones, which have considerably less screen real estate. Additionally, from the study the improvements between 25 and 30 mm button sizes are diminutive (7.5% at 30mm, and 8.8% at 25mm). Another study conducted by (Colle & Hiszem, 2004) show that there is no statistical significant increase in error percentage between 20 and 25mm button sizes. Therefore a 30mm button size may not be feasible, and the overall target button size can be from 20 to 30mm, and for tasks with low error tolerance the target should be 25 to 30mm.

As afore mentioned there is correlation between older adults and PD patients interaction with touchscreens, Some design recommendations targeted at older adults are also applicable to PwPD.
(Al-Razgan, Al-Khalifa, d, & Alajmi, 2012) provides a list of design recommendations for older adults based on extensive literature review. The recommendations are organized into three categories, namely: (1) Look and Feel, (2) Functionality and (3) Interaction, and are as follows:

1. **Look and Feel**
    a. Larger size of mobile phone, that consist of three-dimensional appearance button for touch-screen
    b. Separate keypads for numbers and letters
    c. Good spacing between buttons
    d. Larger font for text, and labeled icons.
    e. In addition, the most important features should be available directly via a labeled button and not via menu navigation.

2. **Interaction**
    a. Easy zoom in and out and pinching.
    b. Tabbing with audio confirmation to help elderly with reduced vision.
    c. Also, the elderly prefers tabbing but not drag and drop actions, voice call, slow motion interface.
    d. The interface should also clearly express where the user is in the dialogue, and which “tasks” are active.
    e. Moreover, the designer should avoid the following for elderly interfaces:
        i. Avoid slide-out keyboard because it bothers the elderly,
        ii. When the touch is lost during dragging, the object should stay where it has been left,
        iii. Do not overload the same object with actions performed by a tap and by a drag gesture, and
        iv. Finally, the screen should not turn off when being idle to avoid confusion. The elder might think that the mobile is not working.

3. **Functionality**
    a. Address book linked with caller identification number along with a picture of the caller, diary, on-screen numbered selections (e.g., press 1 for calendar), i.e. functionality of the same type should be grouped together
    b. The main navigation should be placed identically on all “pages”, and critical functions should never disappear, and important functions should be placed at the top of the screen to avoid mistake touches.
    c. Additional request by elderly to have specific buttons for the following actions: single button to return to the home state, a locking button to prevent accidental dialing, a panic button for emergencies, and a button to place a caller/number into a blacklist.
    d. On the other hand designer has to carefully consider naming programs and commands, not too many or too less features for mobile phone interfaces for elderly.

2.5.3 Design guidelines and Recommendations for PwPD

Through extensive literature review and usability experiments measuring performance of these gestures: tap, swipe, multiple-tap and drag, (Nunes et al) developed 12 design guidelines for smartphone applications intended for people with PD. The 12 Guidelines are as follows:

1. Use tap targets with 14 mm of side.
2. Use the swipe gesture, preferably without activation speed.
3. Employ controls that use multiple-taps.
4. Use drag gesture with parsimony.
5. Prefer multiple-tap over drag.
6. Adapt interfaces to the momentary characteristics of the user.
7. Use high contrast colored elements.
8. Select the information to display carefully.
9. Provide clear information of current location at all times.
10. Avoid time-dependent controls.
11. Prefer multi-modality over a single interaction medium.
12. Consider smartphone design guidelines for older adults.

3 Methodology

3.1 User Requirements

This project is a further development of (Upsahl, Vistven, Bergland, & Chen, 2018). They created the requirements based on an interview with a physiotherapist working with PwPD, and focus group interviews with PD patients and healthcare workers. The user requirements in this thesis are based on the gathered requirement from (Upsahl et al., 2018).The interviews provided detailed requirements and explanations, I created a summary of the main requirements mentioned from these interviews:

3.1.1 Requirements from the physiotherapist

- Physios should help users set up the application at the rehabilitation center
- Reminded by notifications
- Having an exercise plan in the app
- Allowing patients to set up exercise goals
- Users should be able to create exercise themselves
- Health care professional should also be able to create exercises
- Option to add contact info of healthcare personnel

3.1.2 Requirements from the focus group

The focus group interviews included 20 people with PD in various stages of the diseases, all were above the age of 60. The healthcare professionals group consisted of 7 people. The requirements from the focus interview:

- The app must be simple, and not have too many features
- Have a database of exercises to choose from
- Add 8-10 exercises in a daily exercise plan
- Be able to scroll down and choose exercise
- Repeat the plan for the rest of the week
- Option to remove and edit individual exercises from the plan
- Option to add video guides to the exercises.
- A medicine reminder

Key points to take away from these interviews, is that patients might need help to set up the application and use the functionality adequality. In the interview with the physiotherapist it was mentioned that it could be done when patients are visiting the rehabilitation center. However physical visitations might be impossible for some users, a solution were the set up and follow up process can happen remotely over the application would be most viable and inclusive. The physiotherapists and patients should both be able to interact with the system, create exercises, goals and plans. This can be done on the same application, where the two different user types have different functionalities, however this would result in additional features and functionality, which can unnecessarily increase the complexity for both users. One of the main points from the focus interviews was also to keep the application simple with few features. A good solution is to have two separate applications that are interconnected, one for the patients and the other for physios. Furthermore after reviewing the interviews and literature in the section above, the main user requirements elected for the project were as follows:

- Two separate applications one for patients, and one for physiotherapists
- Users (patients and physios) should be able to create custom exercises
- The users should be able to choose pre-existing exercises from a database
- The users should be able to add the exercise to a workout plan
- Ability to remove and edit individual exercises from the workout plan
- Remind user to exercise through notifications
- The application should follow design guidelines for people with PD (Nunes et al., 2016)
- The application should be accessible:
    - Do not include functionality that requires complex gestures such as drag, pinching to zoom, multi-tap.
    - Have a consistent navigational layout
    - Appropriate size and spacing for fonts and buttons

3.2 Technical Environment (Platform)

The application was developed and deployed for the Android platform. Developed by Google and Open Handset Alliance, Android is an open-source Linux-based operating system designed specifically for touch screen devices, such as smart phones, tablets and computers. Android was preferred over Apples iOS operating system due to greater personal accessibility to hardware that supports Android, and familiarity to programming languages supported in Android development Java and Kotlin versus Swift and C++ in iOS application development.

The Android Software Development Kit (SDK) provides tools and libraries required to create Android applications. The application was developed in Android Studio 4.1.1[3], which is Googles official integrated development environment (IDE) for the Android platform. The Android SDK is integrated in and optimized for Android Studio. For each version of the Android operating system, there is a corresponding SDK platform. In this project the chosen SDK platform was API 21, which is compatible with Android 5.0 Lollipop and newer versions. According to (Figure 3-1), the cumulative distribution is 94.1%, meaning that the application will run on approximately 94.1% of Android devices. This version was preferred, as it provided the ancillary functionalities that comes with the newer versions, while also ensuring availability for large number of users.

ANDROID PLATFORM VERSION	API LEVEL	CUMULATIVE DISTRIBUTION
4.0 Ice Cream Sandwich	15	
4.1 Jelly Bean	16	99.8%
4.2 Jelly Bean	17	99.2%
4.3 Jelly Bean	18	98.4%
4.4 KitKat	19	98.1%
5.0 Lollipop	21	94.1%
5.1 Lollipop	22	92.3%
6.0 Marshmallow	23	84.9%
7.0 Nougat	24	73.7%
7.1 Nougat	25	66.2%
8.0 Oreo	26	60.8%
8.1 Oreo	27	53.5%
9.0 Pie	28	39.5%
10. Android 10	29	8.2%

Figure 3-1. The distribution of different Android Versions (Screenshot taken from Android Studio)

[3] https://developer.android.com/studio

3.2.1 Device Emulator – and physical device

Android Studio also provides a QEMU-based Android device emulator. The emulator provides almost all the capabilities of a physical Android device. The emulator allowed for fast testing of the application on different devices and Android API levels. Two emulated devices were used, namely "Pixel 3a" with API level 29 and "Pixel 3" with API level 30, (Figure 3-2).

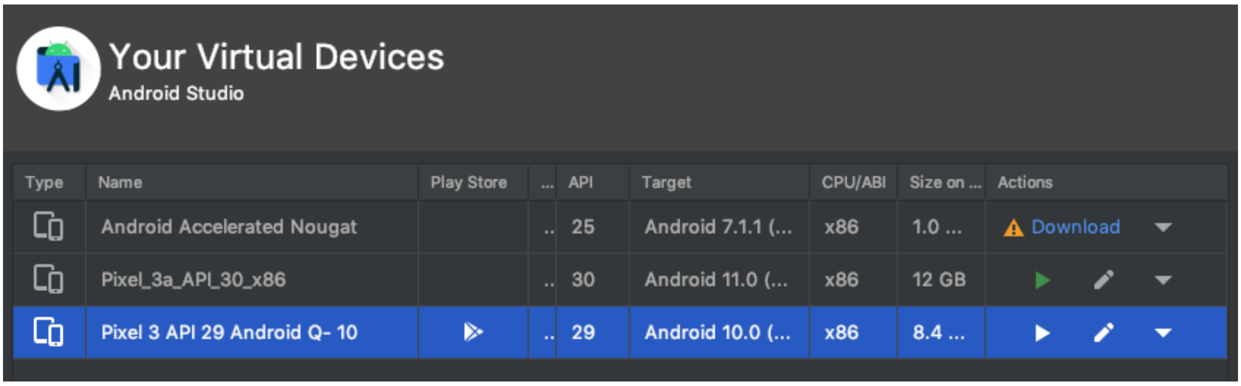


Figure 3-2. The installed virtual devices

Lastly "OnePlus 7 pro" running Android version 11.0 was used as the physical device for real world testing of the application.

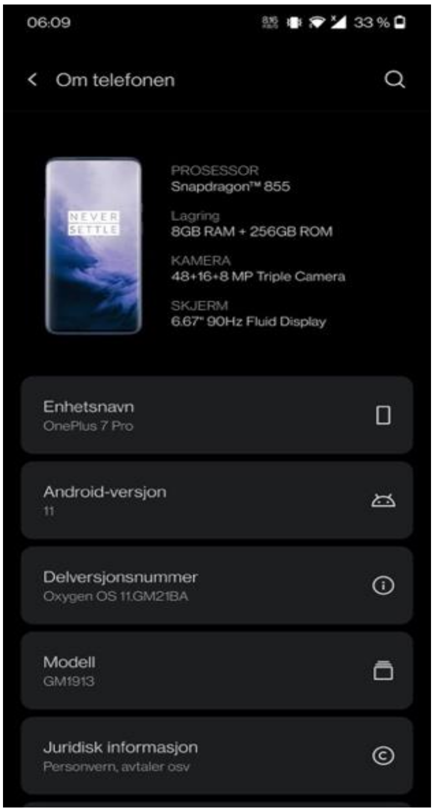


Figure 3-3. System information about the physical device

3.3 Firebase

The authentication system and an online database is provided by Firebase. Firebase is a web and mobile development platform provided by Google. Firebase provides services and tools such as analytics, performance monitoring, authentication, real-time database, file storage, and push messages (Rajappa et al., 2020). These services are hosted in the "cloud", and the backend components are maintained and operated by Google (Stevenson, 2018).

The implementation of Firebase is done very easily through the Firebase console, which is a web based user interface used to manage Firebase services. Firebase creates a unique JSON config file when registering the application, this file needs to be downloaded and added to project application folder (Figure 3-4).

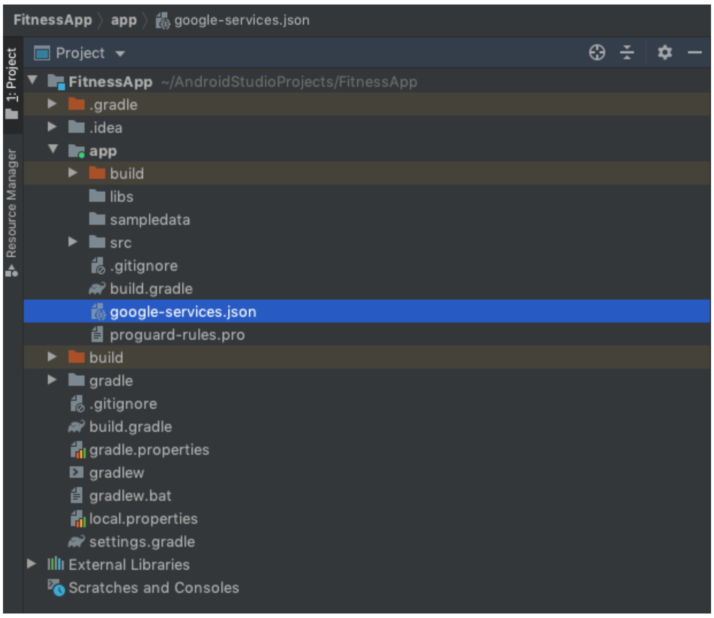


Figure 3-4. The JSON file in the project directory.

Then the dependencies for the Firebase services and SDKs used in this project are declared in the application level build-gradle file, as shown in Figure 3-5.

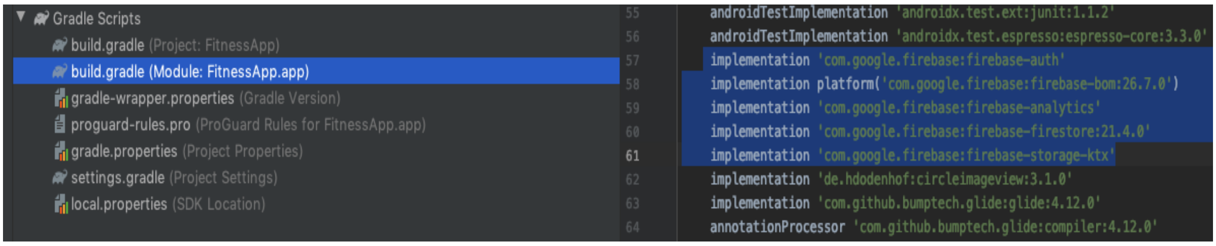


Figure 3-5. Dependencies for the Firebase services.

3.4 Use of Firebase in the project

Firebase is used as a Backend-as-a-Service (BaaS) (Sharma & Dand, 2019) in this project. Administrative access to the services is provided by Firebase Console. The functionalities and services used in the project are (Kumar, 2018):

3.4.1 Authentication

- Firebase Authentication is used in the application to restrict access per-user data.
- Authentication is also necessary for differentiating what data (exercises, workouts) is available to the user.
- Firebase Authentication supports multiple ways of authentication for example authentication through third-party applications such as Facebook, Google, and Microsoft, however since it is a prototype the authentication was kept simple, and it is done through email and password.

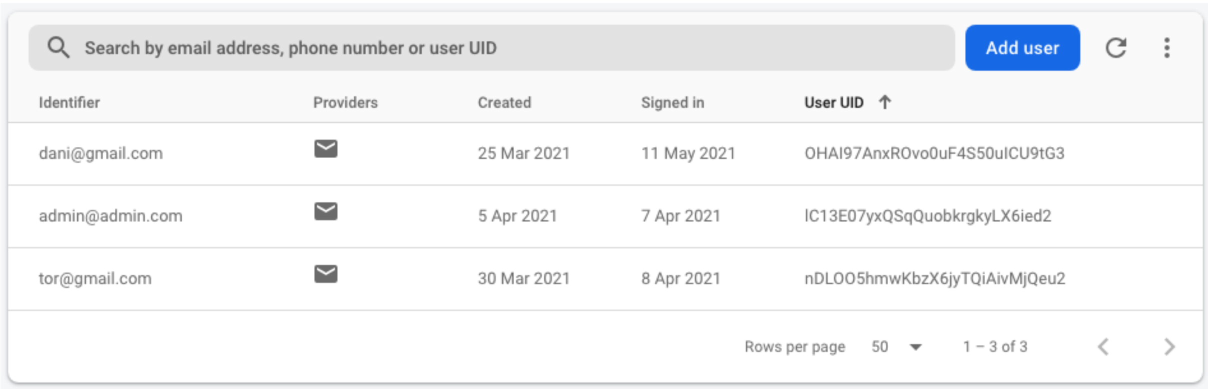
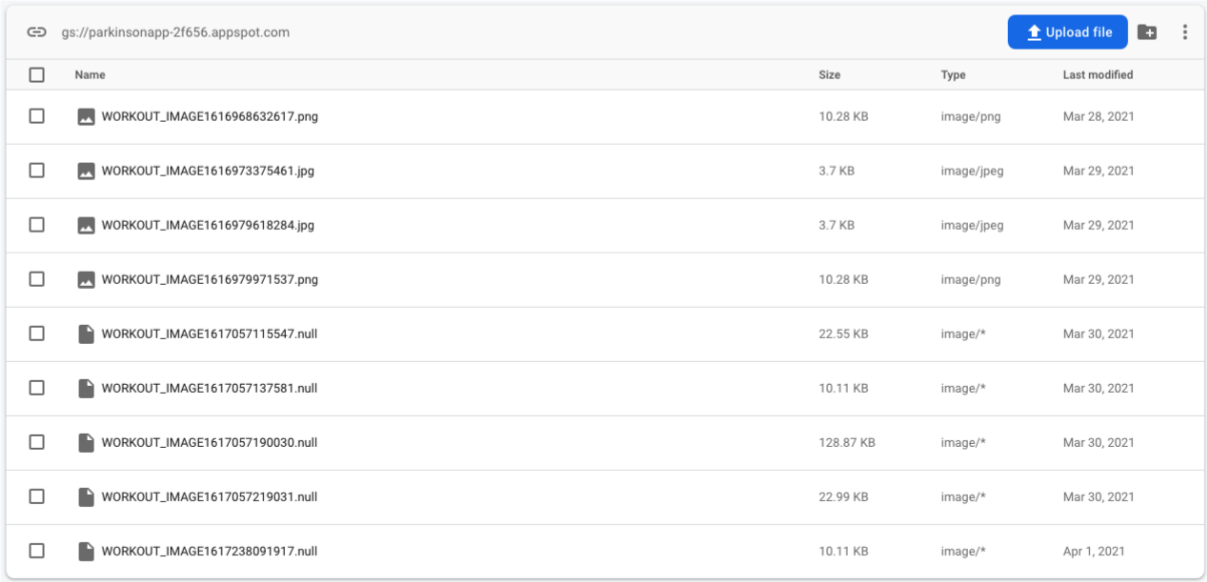


Figure 3-6. The authentication tab in Firebase Console, shows three registered users

3.4.2 Storage

- The Cloud Storage for Firebase, allows the application to upload and download files directly from the cloud storage.
- This service works together with the database. It is used to display the images of the exercise. When a user creates a new exercise the image for the exercise is automatically uploaded to the cloud storage. Similarly when a exercise is displayed on the application, the image is retrieved from the storage and database and then loaded in the application.



gs://parkinsonapp-2f656.appspot.com

Upload file

Name	Size	Type	Last modified
WORKOUT_IMAGE1616968632617.png	10.28 KB	image/png	Mar 28, 2021
WORKOUT_IMAGE1616973375461.jpg	3.7 KB	image/jpeg	Mar 29, 2021
WORKOUT_IMAGE1616979618284.jpg	3.7 KB	image/jpeg	Mar 29, 2021
WORKOUT_IMAGE1616979971537.png	10.28 KB	image/png	Mar 29, 2021
WORKOUT_IMAGE1617057115547.null	22.55 KB	image/*	Mar 30, 2021
WORKOUT_IMAGE1617057137581.null	10.11 KB	image/*	Mar 30, 2021
WORKOUT_IMAGE1617057190030.null	128.87 KB	image/*	Mar 30, 2021
WORKOUT_IMAGE1617057219031.null	22.99 KB	image/*	Mar 30, 2021
WORKOUT_IMAGE1617238091917.null	10.11 KB	image/*	Apr 1, 2021

Figure 3-7. The storage tab in Firebase Console, shows all uploaded files to the cloud storage

3.4.3 Real-Time database

- Firebase offers two database solutions, namely “Real-time database” and “Cloud Firestore”. The Cloud Firestore is the newest release, and provides richer, and faster queries than the Realtime Database (F. Documentation, 2021). Therefore Firestore emerged as the preferred solution.
- It is a NoSQL cloud hosted database. The main strength of the Firestore database is that the data is available to all clients in real-time. Unlike traditional databases that make HTTP calls whenever data is needed, Firestore establishes a web socket connection to the application. Web sockets are a lot quicker than HTTP calls, and only a single connection is necessary. When a data entry is updated the data is synchronized across all connected clients in real-time.
- The database includes three collections: exercises, workouts, and users.

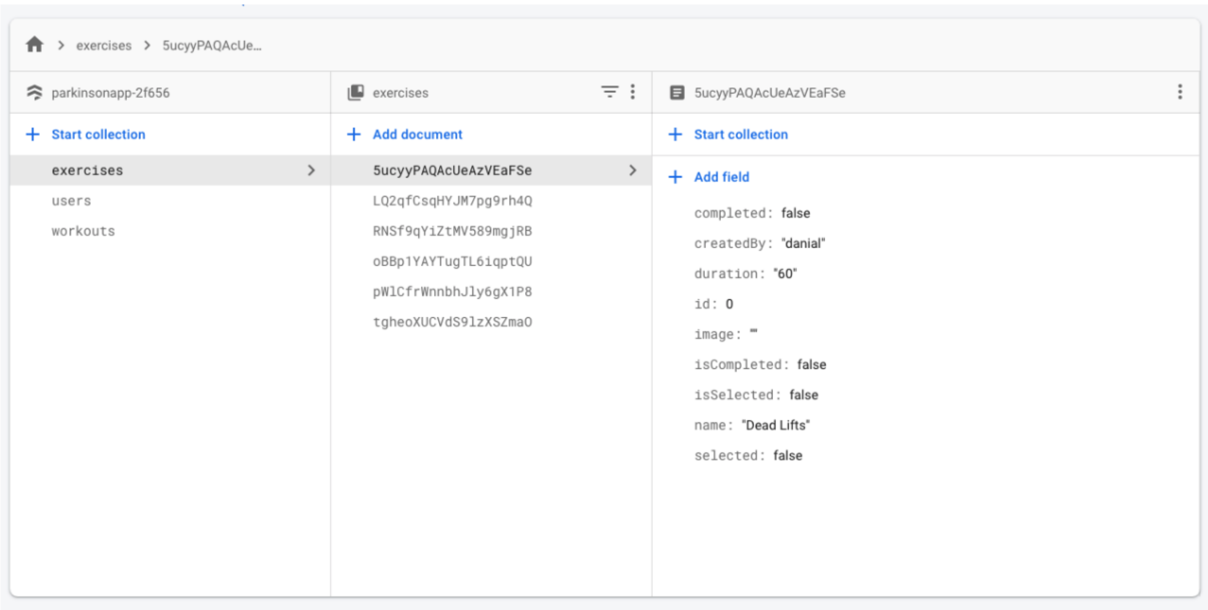


Figure 3-8. Web interface for the FireStore database

The two apps are in the same project, which means they share the same services and resources, such as the database, authentication system, and storage. The reason behind a shared exercise database, is that the user may want to create their own exercises and add them to a workout, or maybe they do not have a lot of knowledge about exercise, as learned from the interviews in (Upsahl et al., 2018). Therefore patients may want to look at exercises created by others to draw inspiration, or to just simply add that exercise to their workout plan.

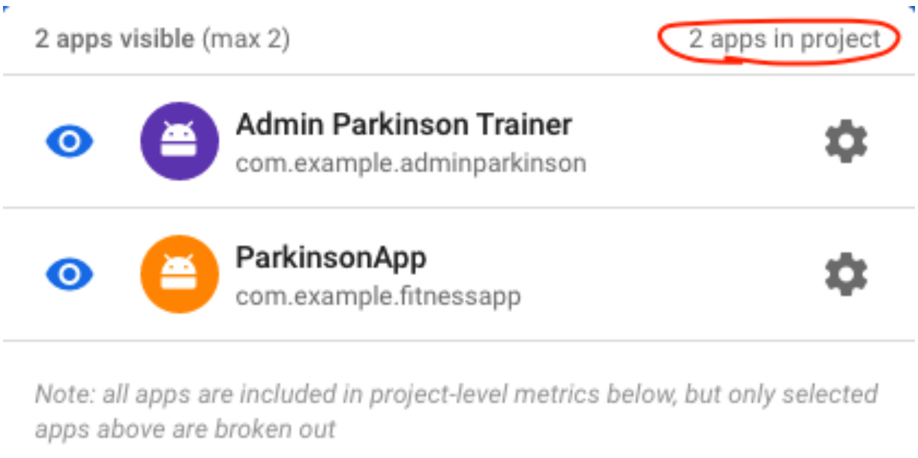


Figure 3-9. Firebase console shows that the project includes two applications

3.5 Software Development Technique

The software development process did not follow any specific development methodology. Most of the popular development techniques are designed for development were teams and customers are involved. This project on the other hand was a lonesome endeavor, however core principles from prominent methodologies such as Agile, Getting Real, and Scrum were followed.

The first step before the development of software could commence, was to define initial requirements for the project. The requirements were accumulated based on extensive research on previous work and literature on application development for PwPD. The requirements were then discussed and agreed upon in the introductory meetings with the supervisor. These were only the initial requirements they were not definitive, the requirements evolved throughout the project life cycle, for example when new work was discovered or unprioritized because of time or resource constraints.

The “Getting Real” methodology initiates the development by focusing on the User Interface (UI) first. The methodlogy suggest perfecting the UI and then building the back end around the front end, since the UI is the only part of the system the end users interact with (Hollar, 2006). Likewise the development process in this project started out with designing the UI, initial sketches of the UI was made in Figma[4] (Figure 3-10).

[4] https://www.figma.com/

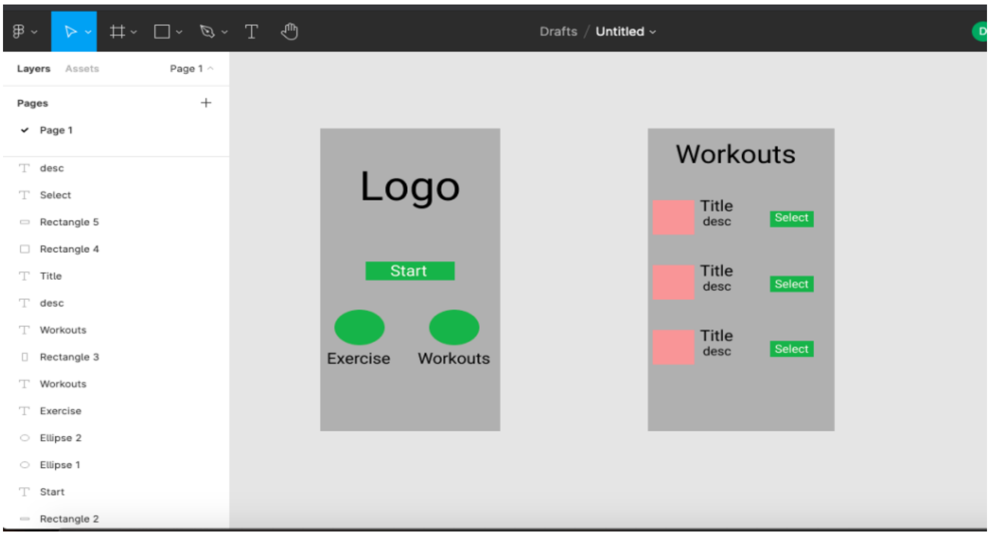


Figure 3-10. Initial sketches of the main screen and workout screen

The project followed an iterative development process. In each iteration a few features were prioritized and added. The code written in each iteration was also reviewed and re-worked for better optimization and readability. Lastly the added features were tested on both the emulated and physical device, before new features were selected for the next iteration. The length of an iteration was dynamic and was determined by the complexity of the feature, but generally one iteration lasted one to two weeks.

3.6 Project structure and Code

All android applications consist of these following four components: Activity, Service, Content Provider, and Broadcaster. The service class is mainly used for long-running processes in the background, such as playing audio. This class was not needed, as all process run while the application is running in the foreground. The broadcast and content provider class have their own unique functionalities, but they are mainly used for data sharing and communication between applications. The communication and data sharing in this project is done through an external third-party online database namely FireStore, therefore these classes were deemed unnecessary and also not implemented in the project. The activity class is used to create a single screen with a UI. The activity class loads the UI elements using a layout file written in XML. Each activity have a corresponding layout file, there also additional layout files for custom dialog boxes, loading screens, and navigation bars. These files are available under the res/layout folder of the project.

All the elements in the layout are constructed using hierarchy of View and ViewGroup objects. The View object is responsible for drawing and event handling, it is what the user sees and interacts with. The ViewGroup is an invisible container that holds other views or viewgroups (Developer, 2020). The hierarchy for the “activity_exercise_list” file, will look like this (Figure 3-11). The file starts with a LinearLayout which is a ViewGroup that contains one View, namely TextView and two other ViewGroups, first one being an AppbarLayout containing a Toolbar view, and second being another LinearLayout which contains a CircleImageView, and RecyclerView. The other layout files have their own unique elements, but the hierarchical structure is the same for all the files.

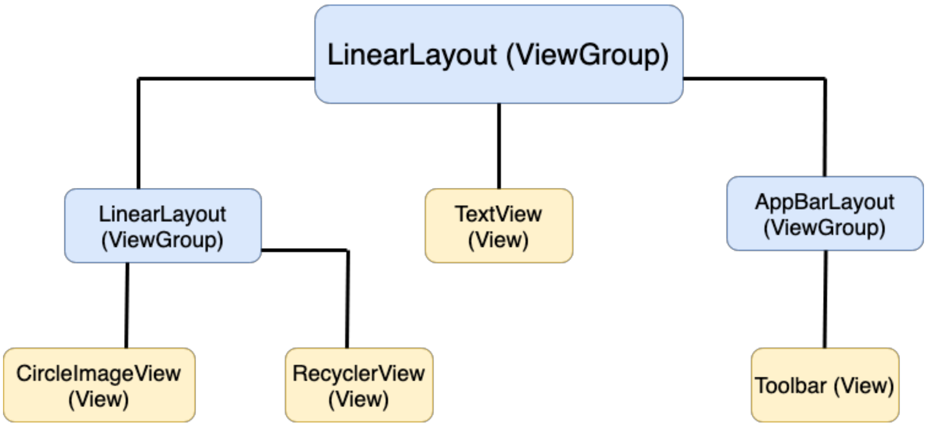


Figure 3-11. Hierarchical structure of view elements in “activity_exercise_list” file

The activity classes are organized under five main categories:

- **Introductory Activities**

  These activities are all the introductory screens displayed when the application is launched. These activities are responsible for creating the view for authentication functionalities, and the main screen from which the user navigates. The following activities are in this category:

  - SplashActivity
  - EntryActivity
  - SignUpActivty
  - SignInActivity
  - UpdateProfileActivity
  - MainActivity

- **Creation Activities**

These activities handles all the views for creation of exercise, workouts, or users. The following activities can be found in this category:

  - CreateWorkoutActivity
  - CreateExerciseActivity
  - SignUpActivity

- **Exercise Activity**
  This activity is responsible for the core functionality of the application, which is to guide the user through a workout. Consequently it is also the most code heavy activity. This category only includes the following singular activity:
  - ExcersiseActivity
- **Auxiliary Activity**
  This activity contains functions that are used throughout all the activities, such as displaying a custom dialog when something is loading, or a dialog for when an error occurs. This activity was made to reduce the code redundancy. All the other activities extends this activity and inherit its functions. The following activity is organized under this category:
  - AuxActivity
- **List Activities**
  These activities are responsible for displaying all the available exercise and workouts. The following activities are in this category:
  - ExerciseListActivity
  - ViewAllExercises
  - WorkoutExerciseListActivity
  - WorkoutListActivity

Each of these list activities have corresponding adapters. An adapter is a bridge between UI component such as ListView, RecyclerView and a data source such as SQLite, or FireStore (Saini, 2016). For instance, to display all the available workouts, the workouts are first retrieved from FireStore (data source), then passed as a ArrayList of workouts to the function "populateWorkoutListToUI" in WorkoutListActivity. Figure 3-12 displays a code snippet of the function were all the components are involved, the retrieved list is marked with blue underline, the UI component is a Recyclerview and is marked with green underline, finally the adapter corresponding to this activity is WorkoutListAdapter and is highlighted with red underline.

```
62  fun populateWorkoutListToUI(workoutList: ArrayList<Workout>) {
63
64      hideProgressDialog()
65      if (workoutList.size > 0) {
66          rv_workout_list.visibility = View.VISIBLE
67
68          no_workouts_available.visibility = View.GONE
69          tv_add_exercise_to_workout.visibility= View.GONE
70          rv_workout_list.layoutManager = LinearLayoutManager( context: this)
71          rv_workout_list.setHasFixedSize(true)
72
73          val adapter = WorkoutListAdapter( context: this, workoutList)
74
75          rv_workout_list.adapter = adapter
76
```

Figure 3-12. Code that shows all the involved components

The ArrayList of workouts is then sent to the adapter (Figure 3-12 code line 73). The adapter makes a view for each item in the data set, meaning a view for each workout in the list (the finalized UI is displayed in Figure 4-6). The complete process is illustrated in the conceptual diagram below (Figure 3-13).

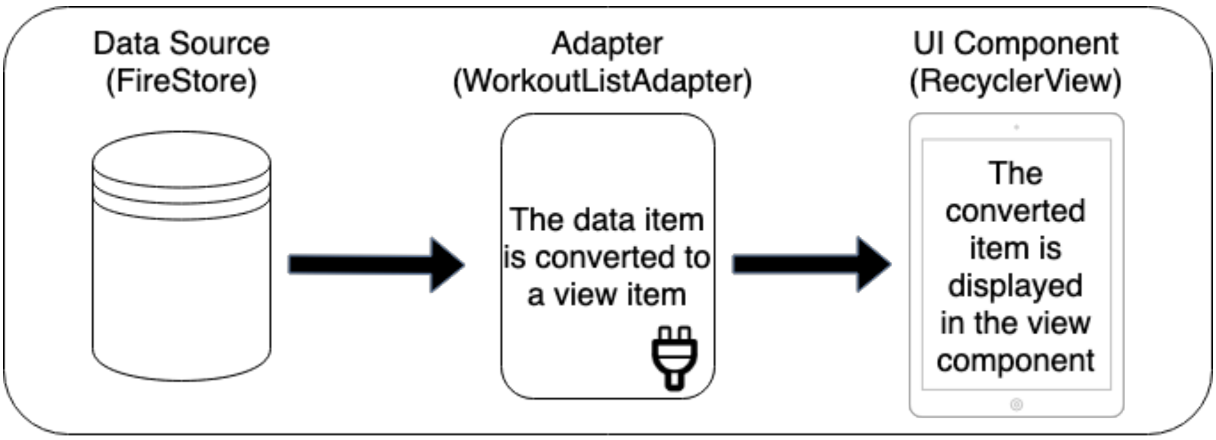


Figure 3-13. The dataset is retrieved from data source, the data is converted in the adapter, and then displayed.

There are a total of five adapters namely:

- AllExercisesAdapter
- ExerciseListAdpater
- ExerciseStatusAdapter
- WorkoutExerciseListAdapter

- WorkoutListAdpter

All the FireStore database related functions that makes queries to the FireStore is organized under one class called FireStoreClass. Functions that uses Firebase's authentication, and functions that manipulate the data in collections is also here. Collections are basically models. There are three models classes in this project for both the applications, namely exercises, users, and workouts. The class diagram Figure 3-14 shows the composition and data fields of the models. A user can be both a patient or a physio. The user can create one or many exercises and or workouts. The exercises and workouts can have no or many users. Whilst the relationship between exercise and workout is that one workout can have many exercises, and an exercise is in one or more workouts.

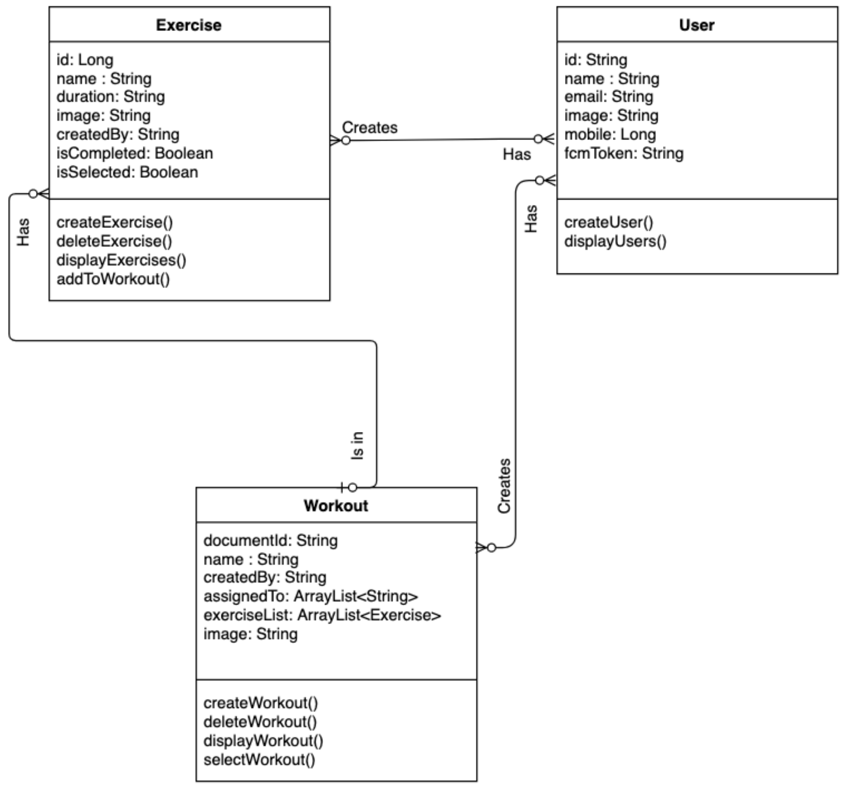


Figure 3-14. Class diagram of the models, the relationship, fields and functions of each model is displayed

The programming language of the application is Kotlin. Kotlin as a programming language is more concise than Java, resulting in less code and fewer bugs, according to (A. Documentation, 2021) android applications that run Kotlin have a 20% less likelihood of crashing. Kotlin is also completely interoperable with Java, therefore some of the code in the application can be found to be in Java.

The complete project code is available on GitHub. The Parkinson Trainer Application: https://github.com/s305231/ParkinsonTrainerApp/tree/master. The Parkinson Admin Application: https://github.com/s305231/ParkinsonAdminApp/tree/master.

3.7 Accessibility evaluation

The accessibility evaluation was done with Google's Accessibility Scanner[5]. The accessibility scanner was downloaded on the physical device from the Google Playstore[6]. The accessibility scanner scans the different screens on the application for accessibility issues. The scanning can be done through single snapshots of the screen or through a recording. The recording allows the tester to establish a workflow and simulate a "normal" interaction with the application, whilst the elements on the screen are scanned and analyzed as the interaction happens. This was the opted method. Two test iterations were conducted, one initial test without any alterations, and a second test after rectifying issues discovered from the first test.

[5] https://play.google.com/store/apps/details?id=com.google.android.apps.accessibility.auditor&hl=no&gl=US
[6] https://developer.android.com/distribute/google-play

4 Results

There were developed two separate applications in this project. One application is meant for the PD patients, and the other is for physiotherapists. They have shared functionalities, but there also some distinct features. I will in this section present a prototype of both applications.

4.1 Start Screen

Before the application starts there is a splash screen. The splash screen displays the application name, “Parkinson Trainer App”, and lasts for two seconds. The main reason for having the splash screen is to provide a smooth transition to the next screen. The next screen is determined in the background, and is dependent upon if the user is logged in or not. If the user is not logged in he/she will be directed to the intro screen. Here the user can either sign in through email and password or sign up. The authentication is handled by Firebase.

The sign up screen has the following three fields:

- Name
- Email
- Password

There is a validation system on the input fields. The fields cannot be left empty, also the name cannot include numbers. The newly created user is then added to the Firestore database, with their respective credentials.

4.3 The Navigation

After a successful sign in the user is directed to the main screen. The main screen includes three screens namely: workout plan, exercises, and start, which again include their own sub screen. The complete navigation flow of the Parkinson Trainer Application is illustrated in Figure 4-1.

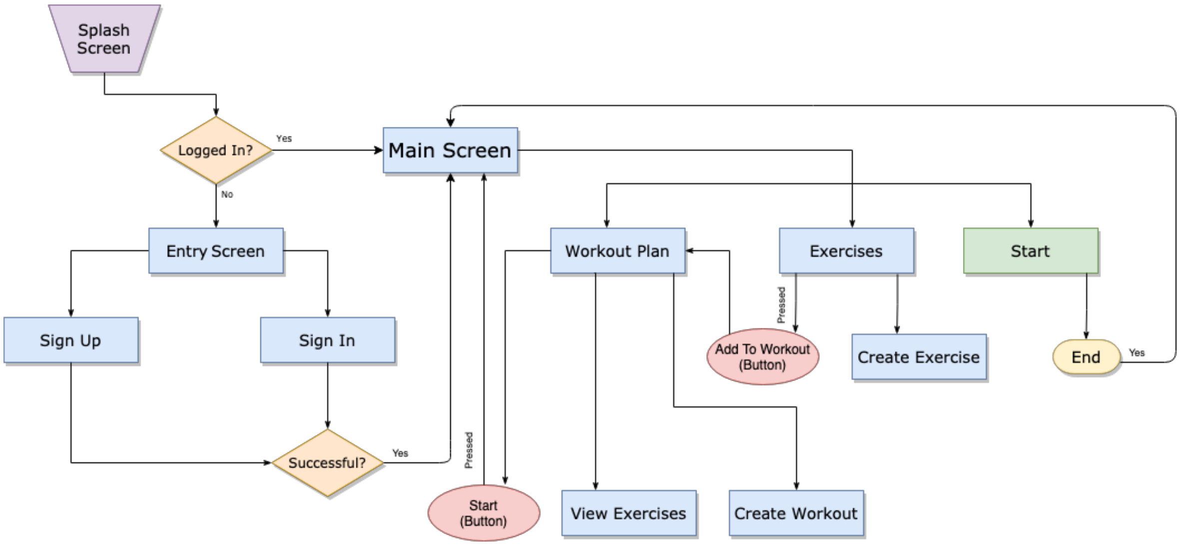


Figure 4-1. Flowchart diagram describing the navigational flow in the Parkinson Trainer Application

The navigation flow of the Parkinson Admin Application is described in Figure 4-2. The sign in process is identical, but this application has its own screen and therefore a dissimilar navigation flow. Each screen and its purpose for both applications is described later in this section

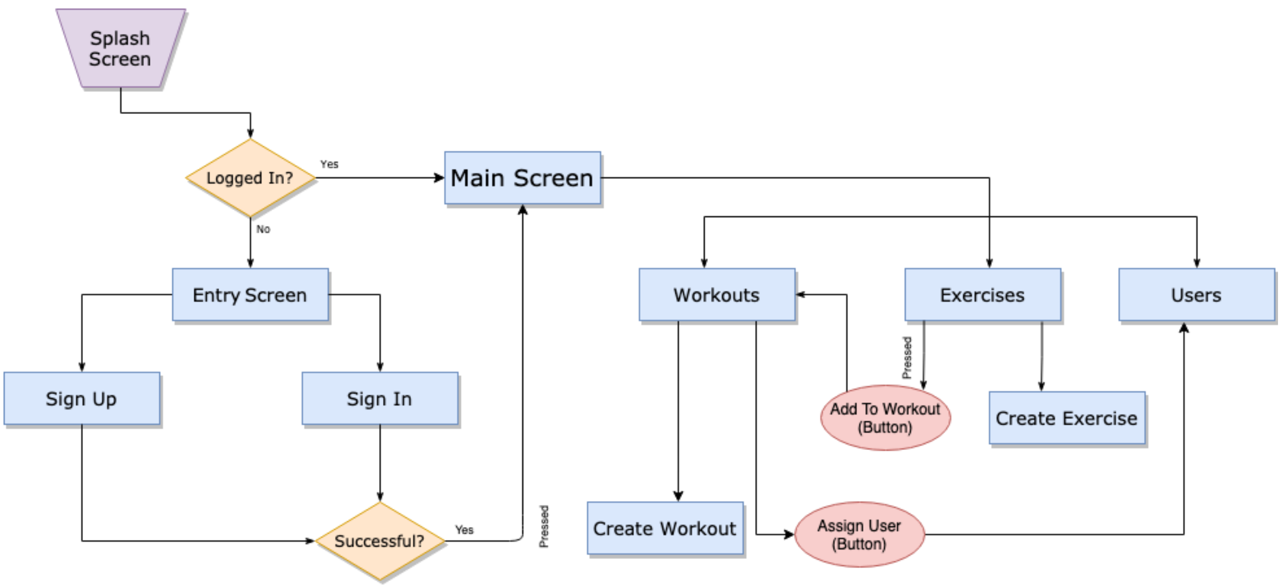


Figure 4-2. Flowchart diagram describing the navigation flow in the Parkinson Admin Application

4.4 Main Screen

The main screen includes three options for the user as shown in Figure 4-3:

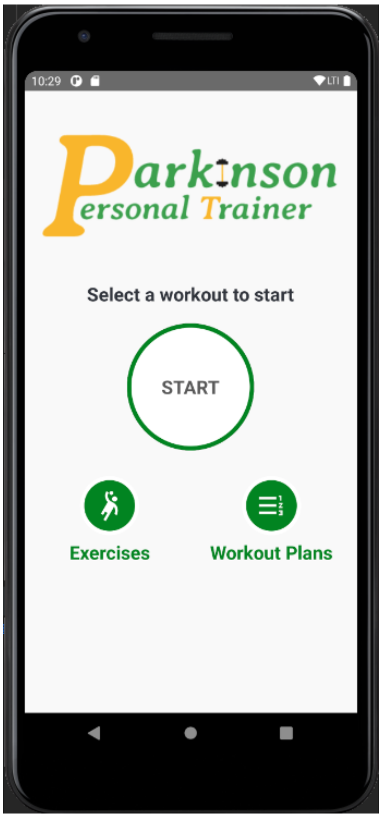


Figure 4-3. The main screen of the Parkinson Personal Trainer

4.4.1 Start

Starts the workout routine, can only be activated if a workout is selected. If pressed without a selected workout the user will be informed via a toast to "please select a workout", and also a text is displayed on the main screen that informs the user to select a workout first. If a workout is selected from the workout list, this button directs the user to the workout session activity described in section 4.5.

4.4.2 Exercises

Here users can view all the exercises stored in the database. The exercises on display are both user created exercises and exercises created by a physiotherapist. The exercises is displayed in a vertical list format, each with their respective image, title, duration, and name of the user its created by as shown in Figure 4-4. Additionally, the users can edit, delete, or create a new exercise.

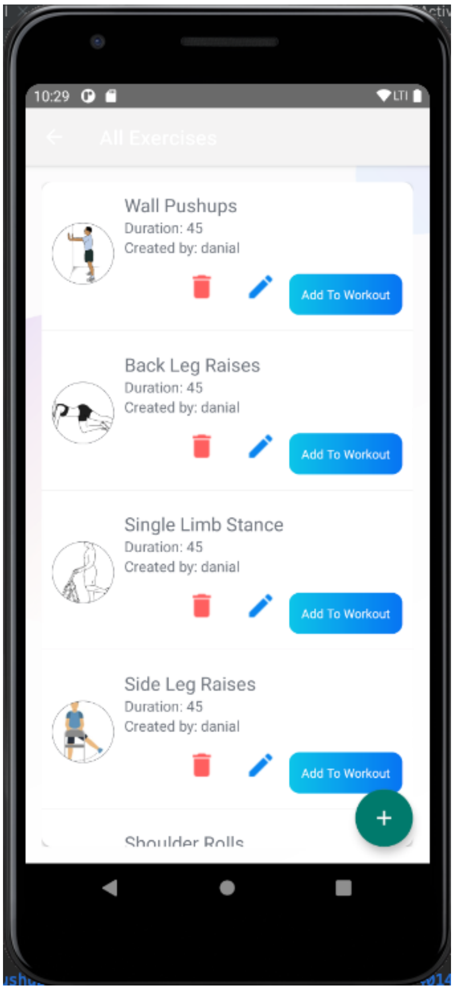


Figure 4-4. Exercise screen, shows list of all exercises on the database

To create an exercise the user has to press the plus button located at the bottom right of the screen. The exercise creation is purposefully kept very simple, at the top there is a circular image, the first shown image is a default place holder image, this indicates that image can be pressed and changed to an appropriate image. When pressed the application firstly asks the user for permission to access the gallery on the user's device. If permission is granted by the user, the user can then choose a locally saved image from their gallery. Secondly there are two input fields, one for the exercise name and the second for the duration time of the exercise. Finally after providing input for all the fields the user can press the "create" button at the bottom, this automatically adds the exercise to the online database, whilst also updating the exercise list to also display the newly created exercise. Each exercise has the "add to workout" option once this button is pressed, the workout list screen is opened and all the available workouts are displayed. A textview is shown on the screen which informs the user to press a workout to add the selected exercise to that workout.

Once a workout is clicked the text changes to “exercise is successfully added to nameOfWorkout”. The user can continue to add the exercise to other workout plans or return to the main screen by using the navigational bar at the top or by performing the back gesture on their device.

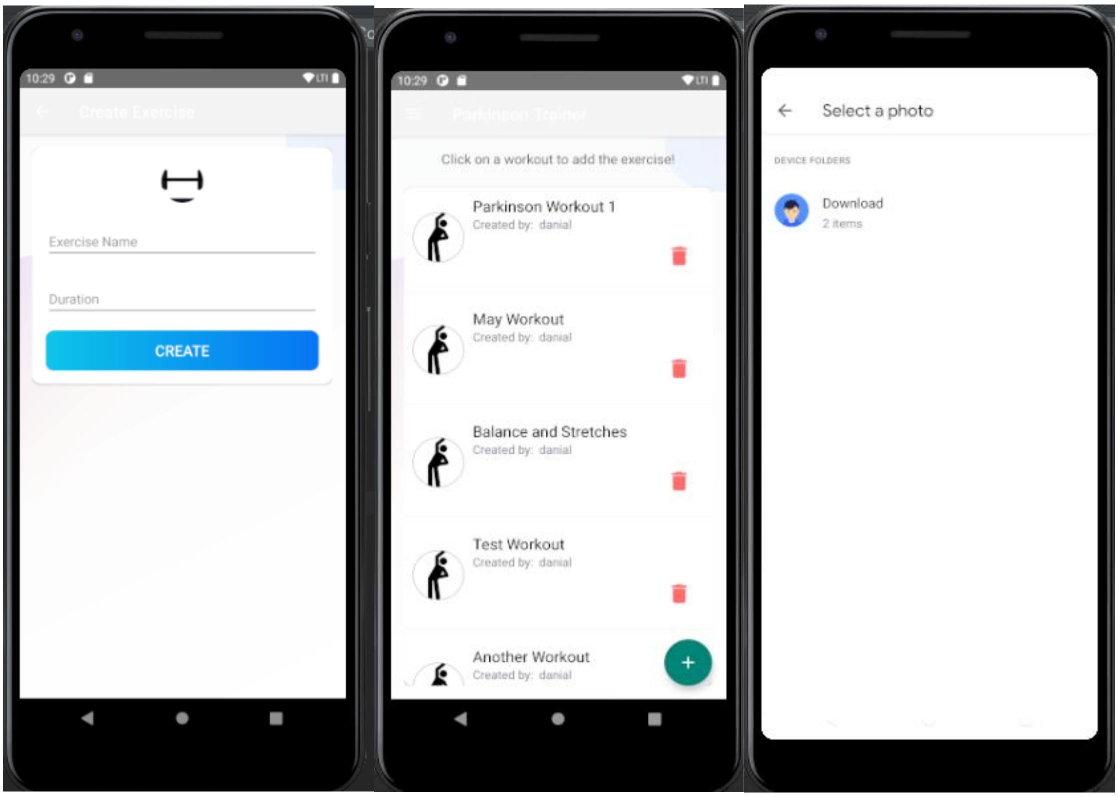


*Figure 4-5. **Left**: Create exercise screen. **Middle**: Workout list to add the exercise. **Right**: User can choose image from their gallery*

10.3.3 Workout

The workout screen is the same screen as the workout screen displayed when the “add to workout” button is clicked in the exercise screen. However, there are different actions available to user depending upon how the user got to this screen. For instance if the user got to this screen by pressing the “add to workout” button, the only clickable event action when a workout is clicked is that the selected exercise is added to the clicked workout. But if the user clicked on the workouts from the main screen, there are different options. Now the user can similarly to the exercise screen delete, edit, or create a workout. The “create a workout” screen only has one input field “workout title” and an image for the workout. The newly created workout is added to the database and subsequentially the workout list is updated to include the latest workout. The workouts contain a list of added exercises. To view the exercises inside a specific workout, the user simply needs to press the workout (Figure 4-6). Lastly each workout inside the list contains a button named “start” as show in Figure 4-6, by pressing this button the workout is selected as the workout to be performed, and the user is directed back to the main screen. Now the “Start” button in the Main screen is clickable, and when clicked the workout session commences.

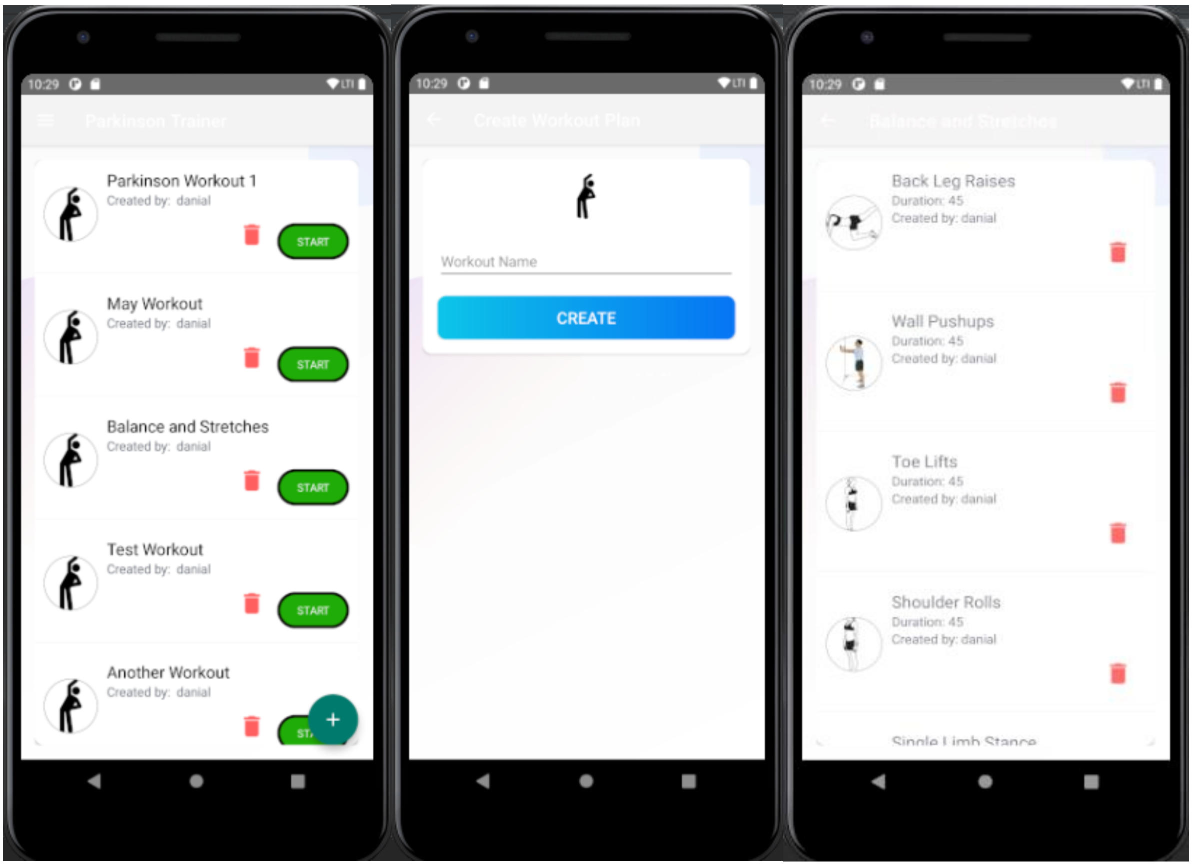


*Figure 4-6. **Left**: Workout list screen a workout can be started from here. **Middle:** Create workout screen. **Right:** Exercises inside a workout.*

4.5 The Workout Session

After the workout is selected and the start button is pressed. The exercises inside the selected workout are retrieved from the database, and loaded into the application. There is only one screen for this activity, the elements on the screen are dynamically changed on this screen based on the progression of the workout. In the center of the screen the exercise image is loaded in. In the workout created for the prototype most of the exercise images are GIFs, downloaded from Spotebi[7]. GIFs are preferred as they can through animation help patients understand how to perform the exercise.

[7] https://www.spotebi.com/

The exercise title is displayed underneath the exercise image, it is also read out through a text-to-speech (TTS) engine. The text was read out successfully when using the application on the physical device, but not on the emulated device. Therefore the TTS is subject to failure, and is dependent upon the device and android version of the device. During a workout it is reasonable to assume that the user may not have constant vision on the screen. Therefore an additional auditory cue is provided when an exercise is completed. This also represented visually through a timer. The timer is equal to the duration time of the exercise, and is decreased every second. The circular numbers on the bottom are equal to the number of exercises in the workout. Once the exercise is completed the according circular number on the bottom is minimized and marked with a green color to symbolize completed exercise as show in Figure 4-7. Before the next exercise in the list is displayed, there is a resting period, the timer is reset to the amount of rest time specified, and the user is informed about the upcoming exercise as shown in Figure 4-7. Finally, when all exercises are completed the user gets a congratulatory message and is returned to the main screen, (Figure 4-7).

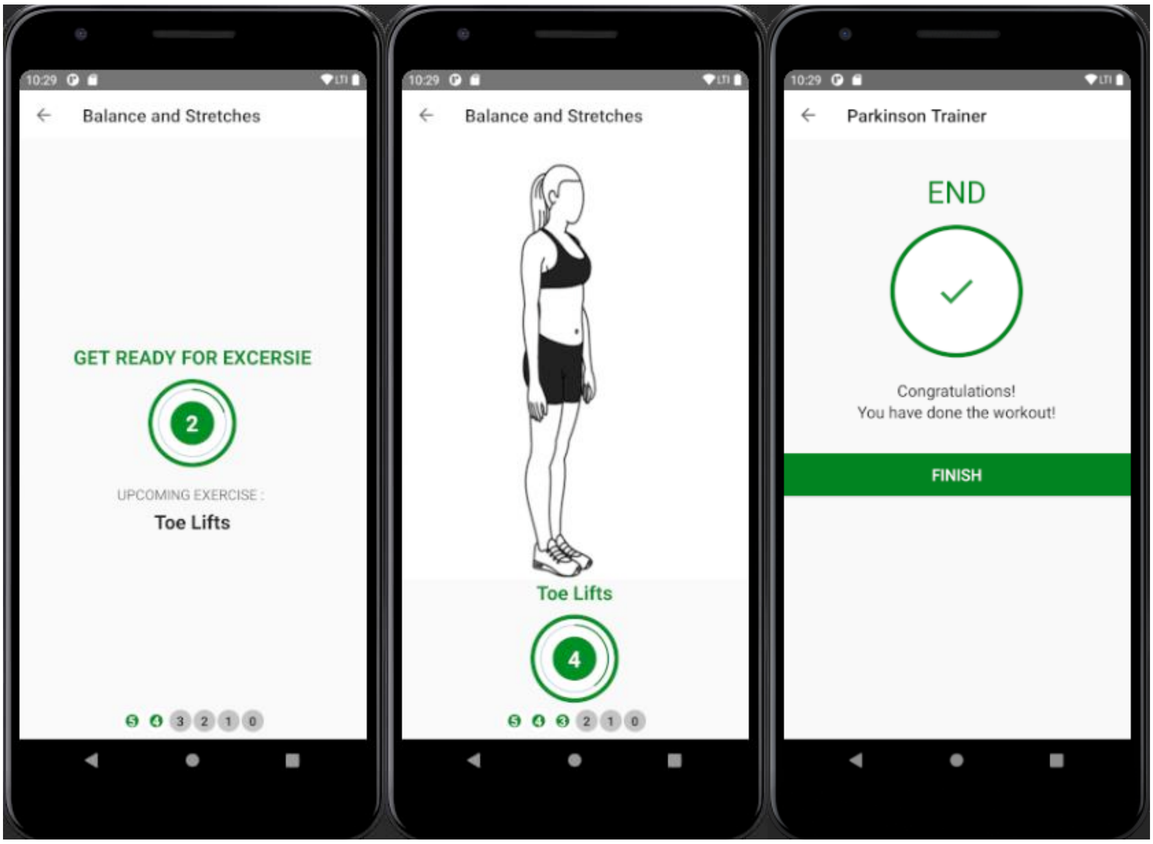


*Figure 4-7. **Left:** The view is changed during resting period. **Middle:** The view during the exercise. **Right:** End screen after workout is completed*

4.6 Parkinson Admin App

The exercise application can be used by everyone even if the user does not have access to a personal physiotherapist. Users of the application can create their own exercises or even choose exercises made by others if found intriguing to create a fitness regimen. However for patients that have personal trainers or physios, having another interconnected application solely for the physios and trainers can prove to be a valuable proposition. “The Parkinson Admin Application” is the second application in this project and it is especially developed for the physiotherapists or trainers of the patients. This application will allow physiotherapists to track patients progress, and also create tailor-made workouts for individual patients.

The design and layout of the application is similar to the exercise application. Identically this application also start off with a splash screen. As of right now only one account is made for the application named “admin”, and if logged in previously, the main screen will be displayed right after the splash screen, if not logged in the user will be directed to a sign in screen. The admin user has access to all the workouts, exercises and users on the system. It is possible to restrict this access, and only make workouts, exercises, and patients related to a specific physiotherapists be available to that physiotherapists.

4.6.1 The main Screen

From the main screen the trainer is able to navigate to three different screens: exercise, workouts, and users. The exercise screen is exactly the same as the one described above for the “Parkinson Trainer Application”. All exercise made by every users is available to the trainer, while the trainer can also create new exercises. The procedure for creating a new exercise is the same as explained above in the other application.

4.6.2 The workout option

The physiotherapist is able to see all workouts on the system both patient and physio created. Additionally, the physiotherapist has the option to assign a workout to a user, as shown in Figure 4-8. This is accomplished by pressing the “assign user” button, this opens up a list of users the physiotherapist can choose from, as shown in

Figure 4-9. After assigning a user this user will now be able to see this workout on his/her application, namely the “Parkinson Trainer Application”.

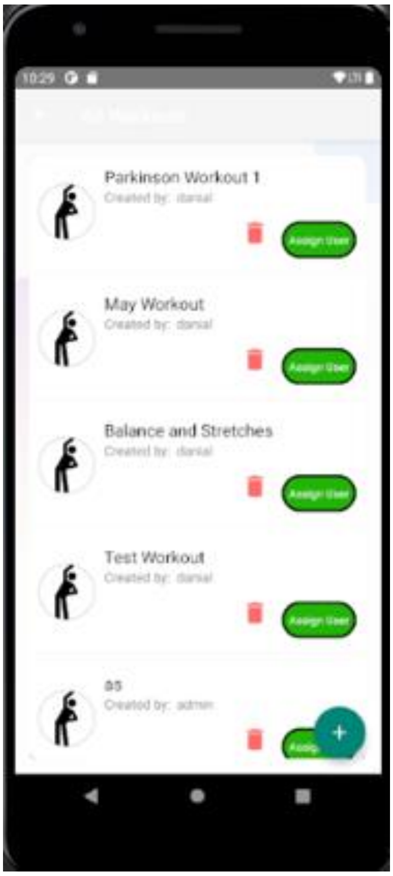


Figure 4-8. The workout screen in the admin app

4.6.3 The users

The final screen for the physiotherapist is the users screen. This screen shows all the current user accounts on this system. Some PD patients may not be able to create a user due to impairments or ineptitude of technology. Therefore the physiotherapist also possess the ability to create users. This is done by pressing the plus sign on the bottom right as shown in Figure 4-9.

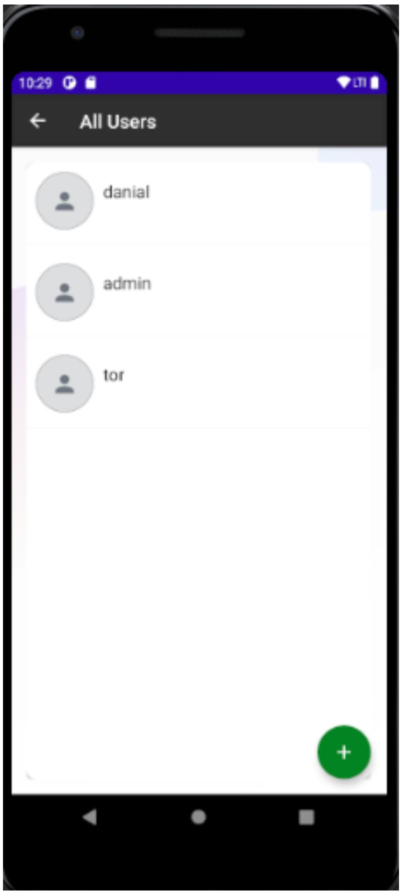


Figure 4-9. The user screen displays all registered users on the system

4.7 Accessibility

The first iteration of accessibility test showcased a few accessibility issues. Most errors were related to inappropriate text contrast and missing alternative descriptions for images (Figure 4-10). There was only one issue regarding size and spacing, and it was for an input text field it was originally 41dp, whereas the accessibility software suggested that it should be at least 48dp, as show in Figure 4-10.

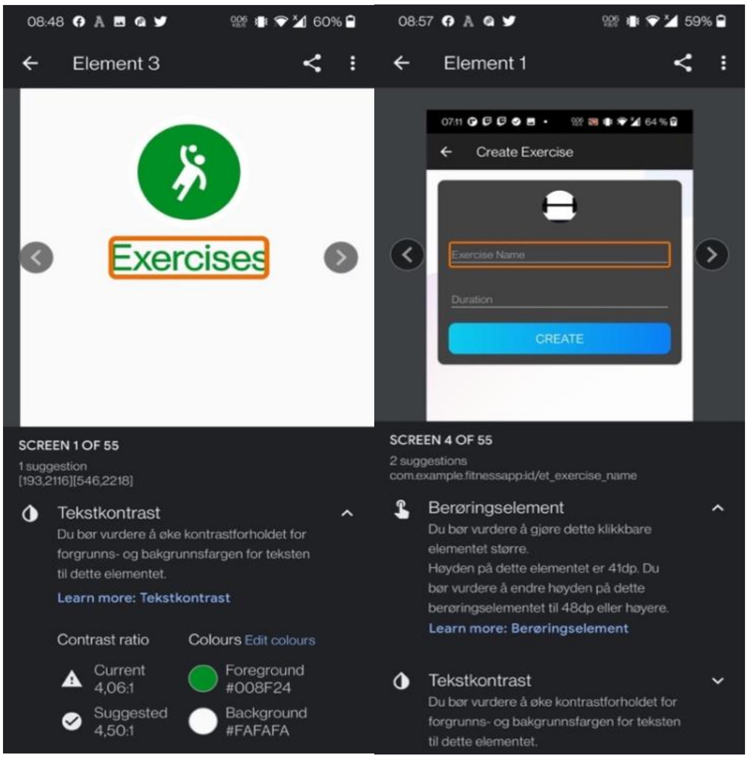


*Figure 4-10. **Left:** Inadequate text contrast. **Right:** Inadequate size for clickable element*

These errors were fixed, and the second iteration of testing did not discover the same or any additional accessibility issues. There were still some minor issues regarding contrast and duplicate alternative text, however this was because of repetitive use of the same button, Figure 4-11 shows that the start button is repeated four times and has the same alternative text. Fixing these issues required a major design change, and were therefore unprioritized and deemed as insignificant issues. Lastly the, “Parkinson Admin App” used the same design elements and color values, consequently the same accessibility issues were discovered and fixed.

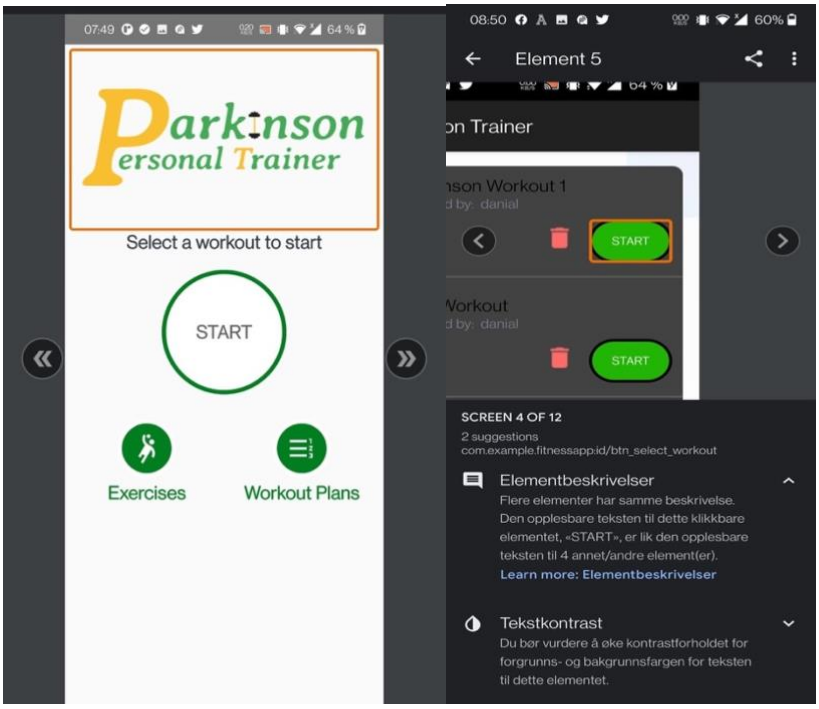


*Figure 4-11. **Left:** previous complaints is gone. **Right:** complaints about repeated description for button*

5 Discussion

Physical therapy and conventional exercise have demonstrated effective relief of symptoms of PD, and in managing and limiting the progression of the disease. Despite the evidence, commitment to exercising can be challenging for a lot of PwPD. The disease severity has a lesser impact on the adherence level, than motivation, support, and ignorance towards exercise. The developed exercise application supplements these impediments, and can prove to be an valuable tool for exercise adherence.

The investigated symptoms of PD, can have a negative impact on interaction with touchscreen based applications. Therefore the application most be at a high level in terms of usability and accessibility. To ensure this, the design was meticulously planned and intended to follow the guidelines presented in (Nunes 2016) and also more general design guidelines recommended for elderly people.

From the 12 presented guidelines the application followed these guidelines:

1. Use tap targets with 14 mm of side.
2. Use drag gesture with parsimony.
3. Prefer multiple-tap over drag.
4. Adapt interfaces to the momentary characteristics of the user.
5. Use high contrast colored elements.
6. Select the information to display carefully.
7. Provide clear information of current location at all times.
8. Avoid time-dependent controls.
9. Consider smartphone design guidelines for older adults.

These guidelines were not followed:

1. Use the swipe gesture, preferably without activation speed.
2. Employ controls that use multiple-taps.
3. Prefer multi-modality over a single interaction medium.

These were not implemented because they were not applicable.

Upon further manual evaluation of the accessibility of the application. It was discovered that the application complies with five of the seven principles of universal design. The infringements are:

Low Physical effort - There are some repetitive actions which can unnecessarily increase fatigue. For instance when the user wants to add an exercise to a workout, each exercise must be individually selected and placed inside the workout. There should be an option to select multiple exercises, and add all the selected exercise at once.

Flexibility in use – There is only one way to interact with the system and that is via touch. It is a mobile application, therefore multimodality is not common practice and is especially harder to incorporate.

The rest of the guidelines are followed.

5.1 Limitation of project

The main limitation of the project is that the developed applications were not tested with users due to time constraint. Only accessibility testing and manual evaluation were conducted. The design and interaction was based on relevant literature review. However, without appropriate user testing it is unfeasible to conclude if the design and interaction was satisfactory and if the developed application agrees with previous literature.

5.2 Future Work

The most imperative future work is to have the application used by PwPD with various symptoms in multiple test environments. Their feedback is needed to achieve a greater understanding of the barriers they face. This can be used to further develop the guidelines for PwPD and help improve the design and interaction for future applications. A longitudinal study is also needed in order to observe the impact level the application has on exercise adherence in PwPD.

The application presented in this project is only a prototype, and it needs further development. A social feature where PwPD can share and track each other's progress can be a useful tool for increasing exercise adherence and motivation. Apart from exercise adherence, additional features can be added to improve other aspects of PD. The literature review suggests that a lot of PwPD also struggle with medicine adherence. A feature for tracking and reminding medicine intake should also be implemented for optimal alleviation of the symptoms. Lastly, users of both applications should have access to a dataset of completed workouts, in order for PwPD to track their progress and also to help physiotherapist monitor their exercise adherence.

6 Conclusion

This thesis has reviewed literature to investigate the influence of exercise in managing symptoms of PD and how smartphone applications can be used to help increase participation in exercise for PwPD. Based on the literature review, an exercise application was developed. The application is a further development of a prototype presented in (Upsahl et al., 2018). The application allows patients access to a database with exercises. The exercises can be created by the patients themselves or from other patients or a physiotherapist. The exercises can then be added to a workout plan allowing users to create a customized workout routine perfectly adapted to their needs. Furthermore, the patient is guided through the workout with visual and auditory cues. In addition a second application especially designed for physiotherapists was developed. This application allows physiotherapists to create custom workouts and assign users to the workout. The design is based on existing guidelines for PwPD and elderly people. However, due to the great level of variation in disease severity and symptoms, it is impossible to have a generalized design pattern, as some guidelines are not applicable to all PwPD. Having a fitting design for PwPD is complex, and a dynamic design that allows for alteration is needed, and if implemented successfully the exercise application can reduce societal encumbrances experienced with PD, and most importantly improve the overall quality of life of PwPD.

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