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A Mobile Exercise app for Users with Parkinson's Disease

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Abstract

Parkinson’s disease (PD) is one of the most widespread neurodegenerative conditions in the world. It is an age-related disease and mostly affects people in the later years of life. The symptoms result in a loss of fine motor skills. The progressive nature of PD and its increasing prevalence have resulted in a substantial economic burden to society, health care providers, individual patients and their family.

Research have shown that physical exercise in patients with PD is an effective method to control PD-related symptoms, reduce or limit the progress of the disease, and improve physical and psychological health. However, due to PD related conditions such as dementia, apathy, excessive daytime sleepiness, and sleeping problems exercise adherence is a challenging task. Since adherence to an exercise program often involves a behavioral change, the addition of support for this process might provide a valuable contribution to adherence. Adherence to exercise programs is fundamental for achieving positive outcomes. Barriers for continuing regular exercise is decline in health, time constraints, and lack of motivation.

The usage of smartphones and tablets is increasing among elderly. Various mobile apps have been developed for older adults, but many of those are not suitable for people with PD, as they do not consider their special conditions.

To support physical exercise among people with PD, a touchscreen prototype that reminds and motivates people with PD to exercise was designed, following guidelines and recommendations for mobile and touchscreen apps for people with PD and taking their special conditions into consideration.

Three iterations of prototypes were developed and evaluated with help from users with PD and health care personnel. A heuristic evaluation based on universal design principles was conducted, and the results were summarized.

Further research is needed to conclude if a mobile exercise app can contribute to exercise adherence for people with PD but based on the response from users involved in this study, it seems possible.

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Introduction

Parkinson's disease (PD) is one of the most widespread neurodegenerative conditions in the world. It mostly affects people in the later years of life, and as the older population continues to grow, the number of people with Parkinson's disease will increase.

Symptoms include tremor in limbs, slowness of movement, stiffness in muscles, and impaired balance. These symptoms result in a loss of fine motor skills which may cause difficulties for people with PD when using smartphones. Medication and various exercises can reduce some of the symptoms, but the effect of treatment will decrease as the condition advances.

PD is an age-related disease that can affect anyone. It is rare before the age of 50, and its prevalence increases with age. There is no cure, and the disease will only progress as the patient ages. It affects between 7-10 million people worldwide, and the economic impact is high, in the United States alone, the combined direct and indirect costs of PD is estimated to almost $25 billion per year.

In recent years, the world's population has increased considerably. Elderly is the fastest growing age group, and the number of people over 60 years is expected to grow to 1.4 billion by 2030, and reach almost 2.1 billion by 2050. This means that the number of people with PD also will increase, therefore it is important to develop systems that can help alleviate the demand on limited healthcare resources.

Physical exercise in patients with PD is perceived to help with controlling PD-related symptoms, in addition to benefitting physical and psychological health (Eriksson, Arne, & Ahlgren, 2013). Even if knowing about the benefits, people with PD may have problems remembering, or might not have the motivation to perform recommended physical exercise.

According to The Nielsen Company (2016), in the United States, 68% of adults over 65 years of age own a smartphone, and 80% of those aged between 55 and 64. In the UK, smartphone penetration is estimated to be 49% for those aged 55-64 and 17% for those over 65 (Lakshminarayana et al., 2017). Therefore, an exercise app, designed for people with Parkinson's, that reminds and motivates, could potentially have a large target group.

1.1 Research goals

The research into developing touchscreen apps for people with PD is limited, but some guidelines and studies exist. Therefore, the research goal of this master's thesis will be the following:

- Create a usable and accessible exercise reminder app for people with PD, that motivates and helps users remember to perform exercises.

The development of the app will follow a user-centered design approach. Existing guidelines and suggestions found in the literature review will be followed. To help with finding gaps in the literature, users with PD will be involved in every phase of the development process.

Developing an app gives the opportunity to analyze existing guidelines and design philosophies for people with PD. Are they valid and reliable? Are they relevant to an exercise reminder app for people with Parkinson's?

The following research questions was constructed to help reach the goal:

- How does PD affect interaction with touchscreens?
- What are the barriers encountered by users with PD when using touchscreens?
- How can touchscreen interaction be improved for people with PD?
- How can an app help with reminding people with PD to exercise?
- How can an app help people with PD with motivation to exercise?
- Create an accessible and user-friendly exercise reminder app for people with PD that motivates and helps users perform recommended exercises.
- Validate guidelines for developing touchscreen apps for people with PD, based on the knowledge gained during the development process, including reviewed literature and feedback from users.

1.2 Organization of this thesis

The rest of this thesis is organized as follows:

In section 2. Background, Parkinson's disease in general, and its motor and non-motor symptoms is described, including those that are likely to affect smartphone use. The importance of exercise for people with PD will also be explained, and why there is a need for a way to remind and motivate them to perform those exercises.

Section 3 contains a systematic review of existing literature covering users with Parkinson's disease and smartphones. This includes how to develop apps specifically for users with PD, how to best include them in a user centered development process, and guidelines and best practices when developing for touch devices and users with PD.

Section 4 describes the research approach and methodology, and section 5 describes the design and development of the exercise app.

Section 6 contains an heuristic evaluation based on universal design principles, section 7 is the discussion, and finally section 8 covers the conclusion and future work.

2 Background

2.1 What is Parkinson's disease?

Parkinson's disease is a chronic and progressive condition, it affects the nerve cells in the brain that control movement, with the most common symptoms being tremor, muscle rigidity, and slowness of movement (The European Parkinson's Disease Association (EPDA), 2017b; The National Institute of Neurological Disorders and Stroke (NINDS), 2017). It is a disease that can affect anyone, without regard to race, gender, or social class (Factor & Weiner, 2007).

PD causes distinctive neuropathological brain changes, with the symptoms appearing gradually, and slowly getting worse over time (EPDA, 2017b). The brain contains nerve cells (neurons) that control movement using chemicals called neurotransmitters, one of them being dopamine (EPDA, 2017b). In people with PD, 70-80% of the dopamine producing cells gradually deteriorate and are lost (EPDA, 2017b). This is called neurodegeneration, and PD is the second most common neurodegenerative disorder in the world, only second to Alzheimer's disease (Factor & Weiner, 2007).

The disease is named after James Parkinson (1755-1824), a practicing general physician who made significant contributions to the medical literature (Factor & Weiner, 2007). In *An Essay on the Shaking Palsy* (Parkinson, 1817), Parkinson was the first to describe, in detail, the symptoms of the disease that would later be named after him.

200 years later, the causes of PD are still mostly unknown, but many investigators believe it "arises from an interaction between genetic and environmental factors that leads to progressive degeneration of neurons in susceptible regions of the brain" (Pringsheim, Jette, Frolkis, & Steeves, 2014, p. 1583).

Diagnosis can be difficult at the early stages, as no tests have proved to help with diagnosing sporadic PD (NINDS, 2017). Medical history and neurological examination are used, but it is still difficult to accurately diagnose or rule out other diseases in the early stages (NINDS, 2017).

PD affects between 7-10 million people worldwide (Parkinson's Disease Foundation (PDF) 2016; Yao, Hart, & Terzella, 2013). In industrialized countries, the prevalence of PD is generally estimated at 0.3% of the entire population, about 1% in those older than 60 years of age, and up to 4% in the oldest age groups (De Lau & Breteler, 2006). In a review of high-quality studies of PD, the prevalence and incidence rates in Europe was estimated to approximately 108 to 257/100,000 and 11 to 19/100,000 per year, respectively (von Campenhausen et al., 2005).

PD severely limits life expectancy, including increased death rate from pneumonia and coronary heart disease compared to patients without PD (Poewe, 2006). In 10 studies examined by Poewe (2006), the mortality rate in patients with PD ranged between 1.5 and 2.5. Following diagnosis, the mean duration until death ranges from 6.9 to 14.3 years (Sveinbjornsdottir, 2016).

Direct and indirect costs of PD is high, in the United States alone, the combined direct and indirect costs of PD is estimated to almost $25 billion per year (PDF, 2016). Lökk, Borg, Svensson, Persson, and Ljunggren (2012) reports an annual direct cost of SEK 76,000 per patient in Sweden, and in 2009, the yearly total direct cost of patients with PD were SEK 1.7 billion.

In recent years, the world's population has increased considerably. From 2015 to 2030, the number of people over 60 years is expected to grow from 901 million to 1.4 billion (United Nations (UN), 2015) The percentage of elderly is also increasing, globally it is the fastest growing age group, and by 2050 the number is projected to reach almost 2.1 billion (UN, 2015). Thus, the prevalence of PD will also increase. In the United States, it is expected to double by 2040 (Kowal, Dall, Chakrabarti, Storm, & Jain, 2013).

The increase in PD prevalence due to an ageing population may cause a "substantially increased burden on society, as well as on the patients and their caregivers" (Lökk et al., 2012, p. 146).

2.1.1 Symptoms

Parkinson's disease is an individual condition, and the symptoms can vary significantly from person to person (EPDA, 2017a). PD is usually diagnosed when the first motor symptoms appear, but symptoms can also be non-motor related (Sveinbjornsdottir, 2016). There are many symptoms associated with PD, and each person affected will experience them to a varying degree.

2.1.1.1 Motor symptoms

The four primary symptoms of PD are "tremor, or trembling in hands, arms, legs, jaw, and face; rigidity, or stiffness of the limbs and trunk; bradykinesia, or slowness of movement; and postural instability, or impaired balance and coordination" (NINDS, 2017).

As described by Parkinson (1817), the patient's first symptoms starts with a slight sense of weakness, and light trembling, most commonly in the hands. The symptoms gradually increase before being sensed in other body parts, usually within a year, e.g., if the symptoms start showing in one hand, it is likely that the other hand will be affected later (Parkinson, 1817).

After a few months, the posture becomes less balanced, the patient starts to lean forward, and one of the legs is likely to start trembling (Parkinson, 1817; EPDA, 2017a). One of the legs usually becomes fatigued faster than the other, and after a few months, both legs will be affected by similar trembling and loss of power (Parkinson, 1817).

Up to this point the symptoms have been subtle, and only a little inconvenience to the patient, except for when using the fine motor skill of the hands (Parkinson, 1817; NINDS, 2017). As the disease progresses, it starts to interfere with daily activities, the patient may experience difficulty walking, talking, or performing other simple tasks (NINDS, 2017). Further examples of motor symptoms can be: difficulty in swallowing, chewing, speaking, and urinary problems or constipation (NINDS, 2017).

The severity of motor symptoms can vary over the course of a day, usually described as the on-off phenomenon (Nutt, Woodward, Hammerstad, Carter, & Anderson, 1984). Some of the random fluctuations in symptoms can be related to the timing of a patients drug administration, but for others the fluctuation seems unrelated to the intake of medication (Nutt et al., 1984).

2.1.1.2 Non-motor symptoms

Non-motor symptoms may start as early as 10 or more years before a PD diagnosis, and can be categorized into "disturbances in autonomic function, sleep disturbances, cognitive and psychiatric disturbances and sensory symptoms" (Sveinbjornsdottir, 2016).

Non-motor symptoms have an increased prevalence as the disease progresses. A study showed that dementia, sleep-wake cycle dysregulation, and autonomic failure were present in 50-80% of patients followed over a 15 year period (Poewe, 2006).

Furthermore, Poewe (2006) mentions a study which shows that about 30% of patients with PD will develop clinically defined dementia. Dementia correlates with faster development of disability. Therefore, delaying the onset and reducing the risk of dementia is important for the overall progression of disability in people with PD (Poewe, 2006).

In another study of 109 patients recently diagnosed with PD, 60-70% showed symptoms such as “a lack of emotional involvement and interest (apathy), excessive daytime sleepiness, sleep problems and constipation” (Sveinbjornsdottir, 2016).

Other symptoms are the “inability to experience pleasure from activities usually found enjoyable (anhedonia) memory complaints, loss of smell and taste, mood disturbances, excessive sweating, fatigue and pain” (Sveinbjornsdottir, 2016).

2.1.2 Treatment

There is no cure for PD, or any treatment that slows its natural progression, but there is a variety of medications that provides relief from the symptoms (Poewe, 2006; NINDS 2017). The response to medication is best at the early stages of PD (Sveinbjornsdottir, 2016).

Not all symptoms respond to medication, and the effect of the medicine vary from patient to patient (NINDS 2017). For some, with the use of medication, symptoms such as balance problems and tremors are reduced marginally, but for others it is not reduced at all (NINDS 2017). Moreover, Sveinbjornsdottir (2016) adds that also gait and balance, speech, and swallowing can respond poorly to treatment. Surgery may be used in some cases when the disease does not respond to medical treatment (NINDS 2017).

Thus, anything that can help slowing down the progression of PD is important for the overall health and quality of life for people with PD.

2.2 Exercise for people with Parkinson’s disease

Poor locomotion and balance in people with PD can reduce their independence and make them more reliant on help from others. Since there is no existing cure for PD, exercise is important to lessen the effect of symptoms, and to help prevent accidents, such as falls.

Several reports over the last 15 years suggest that physical exercise is an effective method to reduce or limit the progression of neurodegenerative diseases (Paillard, Rolland, & de Souto Barreto, 2015). For PD, this is supported by Ashburn et al. (2007); Fisher et al. (2008); Goodwin, Richards, Taylor, Taylor, and Campbell (2008); Tillerson, Caudle, Reverón, and Miller (2003).

There are a few exercise apps for people with PD. One example is 9zest Parkinson’s Therapy. It includes many needed features but does not comply all guidelines and recommendations described in the literature review of this thesis. The app is not specialized for users with PD, 9zest have other exercise apps with same design for other user groups.

2.2.1 Benefits of physical exercise

Several reviews have concluded that physical exercise benefits those with PD in respect to physical functioning, health-related quality of life, leg strength, balance and gait speed (Eriksson et al., 2013). “It is indicated that physical exercise may positively influence activity-dependant alterations in dopaminergic and glutamatergic neurotransmission in PD” (Eriksson et al., 2013, p. 2237).

A study with people with PD by Atterbury and Welman (2017), comparing home-based with therapist-supervised exercise, showed improved stride length and functional gait. This is supported by Lun, Pullan, Labelle, Adams, and Suchowersky (2005), who also emphasize the importance of regular physical activity, as the benefits are short-lived if exercise is not maintained.

Ashburn et al. (2007) performed a trial over a period of 6 months, which showed reduces fall rates for patients with idiopathic PD who performed training exercises in their own home. Near falls and repeated near falls were significantly reduced. The trial suggests that patients with less severe PD benefited to a greater extent from the exercise program (Ashburn et al., 2007).

Exercise may also help against the loss of mental as well as physical abilities: “Exercise programs may be an effective strategy to delay or reverse functional decline for people with PD” (Goodwin et al., 2008, p. 631).

2.2.2 Motivation to exercise

As previously mentioned, some of the symptoms of PD include: apathy, daytime sleepiness, memory problems, fatigue, and pain. These are among factors the can discourage people with PD from adhering to the recommended exercise. Adherence can be understood as the extent to which the patient’s behavior corresponds with caregivers’ recommendations and follows the mutual agreement to achieve established goals.

After a supervised exercise period, measured improvements in people with PD have shown to return towards to baseline values (Ene, McRae, & Schenkman, 2011). Barriers for continuing regular exercise is decline in health, time constraints, and lack of motivation (Ene et al., 2011; van der Kolk & King, 2013).

For individuals with PD that has participated in an exercise study, Ene et al. (2011) concludes that it is important to determine how to “motivate and enable people with PD to engage in these activities and to develop enduring exercise habits. Otherwise, gains made during short-term exercise efforts may be lost” (Ene et al., 2011, p. 39).

The social aspect of exercise is important for motivation. In the previously mentioned study by Atterbury and Welman (2017), the therapist-supervised group were more motivated than those following the home-based program following instructions from a DVD.

Silveira et al. (2013) performed a study on elderly 65 years or older, using a training app running on a tablet, that assists, monitors, and motivates the user to follow a personalized training program at home. The app proved to assist and motivate healthy older adults to perform strength and balance exercises. Social aspects were included, and proved to help motivate the users to follow the exercise program (Silveira et al., 2013).

Ene et al. (2011) conducted interviews with people with PD that had followed an exercise program, and the following motivational factors to exercise was mentioned:

- Following through on a commitment (to exercise).
- Managing the symptoms of PD.
- Encouragement from family members.
- Knowledge that exercising is healthy.
- Hope that exercising will delay progress of PD.
- Seeing positive results from exercise in others with PD.
- Belief that exercise will help with being able to continue participating in other meaningful activities.

(Ene et al., 2011)

3 Literature review

3.1 Literature Review Methodology

This literature review will focus on the following research questions:

- How does PD affect interaction with touchscreens?
- What are the barriers encountered by users with PD when using touchscreens?
- How can touchscreen interaction be improved for people with PD?

To find literature relevant to designing touchscreen apps for people with PD, specific search terms and inclusion criteria for data collection were specified. Those search terms included keywords such as Parkinson's disease, tremor, shaking, smartphones, mobile, touch, touch device, touch interaction, app, development, accessibility.

3.1.1 Literature search and database selection

There is limited research into development of smartphone apps for people with PD, and few sets of guidelines exists. Therefore, the main objective of this analysis is to:

- 1. Carry out a systematic literature review to examine the current state-of-the-art of smartphone app development for people with PD, including:
  - Guidelines.
  - Design methods.

PD is a disease that mainly effects persons in the later stages of life (aged 50+), and many guidelines for how to develop for elderly smartphone users exists. Design guidelines for elderly cover some of the symptoms of PD, but not all. Thus, the second objective is to find:

- 2. Which symptoms of PD affect interaction with touch screens?
- 3. What are the barriers people with PD encounter when using touch screen?

A systematic approach will be used to identify relevant papers and studies through a methodical search of academic online databases and search engines, such as: Google Scholar, ACM, Springer, IEEE Xplore, Web of Science

3.1.2 Search terms

To select appropriate papers for inclusion in the review. The following criteria were used:

- Articles published between January 2006 and May 2017.
- Articles must involve the use of touch devices, such as smartphones or tablets.

- Articles must address one of the following:
    - how to develop for people with PD.
    - how to develop for the symptoms of PD, such as tremor, and shaking of the hand.
    - how to work with, and how to best involve people with PD when testing touch device apps.
- Articles must include at least one combination of the search keywords, i.e., target group + touch devices:
    - Parkinson’s OR tremor OR shaking AND touch OR smartphone OR app.
- Articles must be from peer-reviewed publications.

3.1.3 Evaluation of relevance

The gathered data was then screened according to the objective of the literature review. Only articles written in English were included, and abstracts were reviewed for the articles that met the specified inclusion criteria. If the article met the objective, it was downloaded and thoroughly reviewed. 24 of the 76 articles found remained after this step.

3.1.4 Analysis of selected articles

The search results were combined and condensed. 9 articles were excluded due to not being relevant, and 1 for not being peer reviewed. By cross checking citations and references, 3 articles were found and added to the review. A few articles previously rejected in were added back into the review at this stage, as other articles cited relevant information from them that was not mentioned in the abstract.

3.1.5 Overview of Articles

References	Methods / Subjects	Research aim	Research results
Barros et al. (2013)	Interview: 5 people with PD, 1 caregiver, 1 physical therapist. Focus group: 2 people with PD, 2 caregivers. Use cases: 3 medical doctors. Usability study: 9 + 12 people with PD over two rounds.	User-centered design involving people with PD. Design and development of four smartphone applications for self-management of PD.	The user-centered and participatory design approach was efficient. Involving end-users in the design process is useful. The iterative process contributed to improved usability results from each test.
Chen, Savage, Chourasia, Wiegmann, and Sesto (2013)	38 participants with motor control disabilities and 15 without.	Investigate the effects of button and gap size on performance by individuals with varied motor abilities.	As button size increased, there was a decrease in misses, errors, and time to complete tasks. Gap sizes did not have a significant effect on performance.
Lakshminarayana et al. (2014) & Lakshminarayana et al. (2017)	158 patients across England and Scotland completed the study over a 16-week period.	Using a smartphone-based self-management platform to support medication adherence and clinical consultation in Parkinson’s disease	After 16 weeks, the app significantly improved adherence, compared to treatment as usual. Both articles include details about the interface of the Parkinson’s tracker app.

References	Methods / Subjects	Research aim	Research results
McNaney et al. (2014)	Interviewed 5 people with PD about their smartphone use.	Explored how Google Glass could be used as an assistive device for people with PD.	Relevant to this review were the problems encountered by people with PD when using smartphones.
McNaney et al. (2015)	Two studies, one with clinical staff, the other with people with PD. 8 participants aged between 46 and 78, ranging from 1-4 on the Hoehn and Yahr scale.	Development of rehabilitative exergames for people with PD.	Describes the importance of including people with PD in the design process. Describes difficulties when including people with PD in the design process.
Montague, Hanson, and Cobley (2012)	12 adults with diverse motor and visual impairments. 6 of them had tremor or spasms in their hands.	An evaluation of the use of shared user modelling and adaptive interfaces to improve the accessibility of mobile touch-screen technologies.	Results indicated significant benefits from the shared user models that can automatically adapt interfaces, across applications, to address usability needs.
Montague, Nicolau, and Hanson (2014)	Conducted an “in-the-wild” user study over 4 weeks. All 9 subjects had different levels of hand tremors. 5 of those had PD.	Measure and understand the variance of touchscreen interaction performances by people with motor-impairments. Measure was performed using a Sudoku game.	Performance varied significantly between users, and individual performance varied significantly between sessions. Proposes tap gesture recognizers to accommodate for individual variances when interacting with touchscreens.

References	Methods / Subjects	Research aim	Research results
Nicolau and Jorge (2012)	15 users aged 67 to 89 (mean age 79). 8 users had varying levels of hand tremor.	Measure elderly’s text-entry performance on touchscreens.	Results showed higher error rates compared to younger users. Hand tremor strongly correlated with input errors. Provided 8 suggestions to improve text-input
Nunes, Silva, Cevada, Barros, and Teixeira (2016)	Researched relevant literature, interviewed healthcare professionals, observed smartphones users with PD, and performed a usability study with 39 people with PD.	How does PD affect the use of smartphones? How to improve smartphone interaction for people with PD.	Created UI design guidelines for smartphone applications for people with PD. Describes how PD affects the interaction with smartphones.
Plaumann et al. (2016)	N/A	How can motion sensor data be used to gain higher accuracy and decrease interaction time for persons with tremor?	An algorithm designed to overcome oscillations issues by detecting the tremor with motion sensors. The detected oscillations are then used to correct users input.

References	Methods / Subjects	Research aim	Research results
Sesto, Irwin, Chen, Chourasia, and Wiegmann (2012)	52 participants. 23 with fine motor control disability, 14 with gross motor control disability, and 15 with no disability. Button sizes varied from 10 mm to 30 mm, and button spacing was 1 mm or 3 mm.	Investigate the effect of button size and spacing on touch characteristics (forces, impulses, and dwell times) during a digit entry touch screen task. A secondary objective was to investigate the effect of disability on touch characteristics.	Button size, but not spacing influenced touch characteristics during a digit entry task. The gross motor group had significantly greater dwell times and impulses than the two other groups.
Trewin, Swart, and Pettick (2013)	Interviews and observation with 16 individuals, some with difficulty in coordinating movement, muscle weakness, and tremor.	Examines the use of touchscreen smartphones, focusing on physical access.	Tablets are an advantage over smartphones, due to size. Describes usability problems not currently addressed by accessibility options. Summarizes the physical and visual access features of Apple iOS 6.1.3 and Google Android 4.2.2.

References	Methods / Subjects	Research aim	Research results
Wacharamanotham et al. (2011)	10 participants with varying degrees of tremor, aged 58-87, mean = 73.	Find a way to decrease error rate without using more screen space, such as increasing target size and space between targets. Will swabbing be more accurate than tapping? Will users be satisfied with swabbing?	Confirms that, swabbing, i.e., sliding the finger across the screen helps reduce tremor. Swabbing was slower than tapping. The researchers believe swabbing will make touchscreens more accessible to older users.
Wacharamanotham, Kehrig, Mertens, Schlick, and Borchers (2013)	20 participants aged between 62-87. 12 with intention tremor, and 8 with parkinsonian tremor.	Discuss how involuntary jittering movements of tremor influences users' input on touchscreens.	Description of preliminary design of a touchscreen web browser for users with hand tremor.
Wiegand and Patel (2015)	15 participants with progressive neurological disorders (none with PD). Average age: 56.	Motor skills assessment study, comparing tapping and sliding tasks on a touchscreen tablet.	Touchscreen interfaces should enable users to relocate buttons away from edges and closer to optimal touch areas. Users should be able to toggle swiping and tapping gestures.

References	Methods / Subjects	Research aim	Research results
Zhong, Weber, Burkhardt, Weaver, and Bigham (2015)	Laboratory study with motor-impaired users. Compared magnification and descriptive targets list to conventional tapping.	Reduce challenges faced by users with hand tremors.	Developed experimental system-wide assistive service called Touch Guard for Android. Enhanced area touch: magnification and descriptive targets list. Targets list reduced the error rate by 65% compared to conventional tapping.

Table 3.1 List of articles included in the review about designing for people with PD.

3.2 Symptoms that effect smartphone interaction

Tremor and loss of fine motor skills can cause great difficulty and frustration when using touchscreens for people with PD (McNaney et al., 2014). The challenges experienced are mostly related to touch screen gestures (Zhong et al., 2015). Nicolau and Jorge (2012) measured text-entry performance on touch devices and found that errors correlated with the users' tremor profiles. One solution is using motion sensor data, which can be used "to gain higher accuracy and decrease interaction time for persons with tremor" (Plaumann et al., 2016, p. 357). Voice commands can be an option for some, but for others unintelligible speech makes this solution less useful (McNaney et al., 2014).

The previously mentioned, unpredictable, on-off phenomenon in PD can change the user's ability to interact with a smartphone depending on the situation. This is supported by Montague et al. (2014), they found that ability and performance between sessions, varied in individuals with motor-impairments.

3.3 Design Principles and Techniques

Barros et al. (2013) found their user-centered design approach to be efficient, the usability tests gave them the opportunity to evaluate the requirements that were defined and implemented along the way.

3.3.1 Involving people with PD

There is limited literature focusing on smartphone interfaces for people with PD. McNaney et al. (2015) performed two studies. The first, a proof of concept game for Microsoft Kinect for rehabilitation and exercise for people with PD. The second, a user-centered design process involving people with PD.

3.3.2 Difficulties when involving people with PD in the design process

One challenge mentioned by Barros et al. (2013) when involving people with PD, is the fact they might not be always available to the design team. It is important to reduce the number of visits and to gather as much information as possible when visiting users (Barros et al., 2013).

McNaney et al. (2015) experienced that people with PD endure a variety of symptoms, which can make this user group difficult to design for. As basis for creating their own framework for people with PD, they used existing guidelines for participatory design with elderly users. This method proved to inadequately address several specific issues with PD, and the four main problems were:

3.3.2.1 Speech

Speech problems are common in people with PD, and can create a communication barrier when involving them as participants (McNaney et al., 2015). People with PD may have trouble verbalizing thoughts, or pronounce words clearly (Barros et al., 2013). To avoid misunderstandings, involving caregivers during interviews may help to clarify or rephrase what is being said (Barros et al., 2013).

This barrier can affect the quality of data collected. McNaney et al. (2015) used a group size of 8 people with PD and reflected that this was too many to facilitate the participation of the whole group. Therefore, McNaney et al. (2015) recommend that future designers could benefit from using smaller groups.

3.3.2.2 General Mobility and Dexterity

McNaney et al. (2015) continues to describe difficulties when people with PD participate in user testing. Motor problems can make it difficult to move around, enter an elevator, sitting down and getting up, etc. The testing environment should therefore facilitate people with PD. Decreased fine motor ability and tremors make can make it difficult for some users to interact with low fidelity prototypes. In a group setting it could be embarrassing for those with reduced motor ability when using craft based prototypes. McNaney et al. (2015) solved this by using digital prototypes. Barros et al. (2013) used paper prototypes with older people without PD to find the best options for elements in the app and to evaluate affordance, before moving on to digital prototypes and testing with people with PD.

3.3.2.3 Medication

According to McNaney et al. (2015), the timing of medication intake can affect people with PD, particularly those with fluctuating symptoms. Each session should therefore follow a strict schedule, and participants should know when to expect breaks. Participants may be experiencing different severity of symptoms from one day to another, which could affect the results when testing over multiple days.

Thus, even if not all people with PD have predictable on-off times, McNaney et al. (2015) recommends that testing should be conducted at the same time of day each session to minimize the effect of fluctuating symptoms.

3.3.2.4 Age Differences

McNaney et al. (2015) observed a difference amongst participants based on age. The younger users were more experienced with the use of technology and might have been more able to associate the games with current games on the market.

3.3.3 Assistive solutions for users with tremor, including people with PD

In addition to the accessibility features included in the Android and iOS operating systems, there have been several studies into various solutions for improving accessibility and usability for smartphones and touchscreens. Following is an overview of different solutions for how to make touch devices more accessible to people with PD.

3.3.3.1 Operating system accessibility features

Some accessibility features that may be of use for people with PD when using a smartphone:

Touch, and *Hold Delay* on Android gives the option to set the delay time before a tap is registered as a long tap (Trewin et al., 2013).

Assistive Touch on iOS gives users the option to use one finger to perform gestures that usually requires more than one finger (Trewin et al., 2013).

Guided Access on iOS locks the device to one app, and requires a passcode to switch to another app (Trewin et al., 2013). This can be used to prevent accidental actions that closes the currently running app (Trewin et al., 2013).

3.3.3.2 Shared user model

Montague et al. (2012) outlines a “shared user modelling approach to adaptive interfaces in designing interfaces for individuals” (Montague et al., 2012, p. 157). The study used three different smartphone apps, in both laboratory and in real world settings.

> User models (UM) provide software applications with context such as user abilities, the domain knowledge of the user, user goals and interests, and their background outside this domain. UM contain a structured collection of information about an individual user, to be utilised by adaptive systems in order to provide a tailored experience within an application. (Montague et al., 2012, p. 152)

The results showed significant benefits since UM can automatically adapt interfaces to address usability needs.

3.3.3.3 Touch Guard

Zhong et al. (2015) describes *Touch Guard*, a background service running on devices with the Android operating system that improves system-wide accessibility and usability of touchscreen interaction. It shows that there is a potential for using software based solutions to make touch devices more usable for individuals with motor impairments (Zhong et al., 2015).

Touch guard’s main feature, *enhanced area touch*, reduces the need for fine pointing, and improves performance for motor impaired users (Zhong et al., 2015). It allows users to select small and dense targets without the visual and physical effort required by steady tapping, since this can be difficult for motor impaired users. It includes two modes: magnification, which failed to improve accuracy and speed; and target lists, which successfully and significantly reduced errors when selecting small and dense targets (Zhong et al., 2015).

3.3.3.4 Button size

Chen et al. (2013) studied the effects of button and gap size, and the presence of disability, including PD, on user performance using a touch screen kiosk. When button size increased, there was a decrease in misses, errors, and time to complete tasks (Chen et al., 2013). 84% of the disabled participants preferred a button size of 20 mm or larger, while a 3 mm gap size was preferred over 1 mm, for both the disabled and non-disabled participants (Chen et al., 2013). A related study by Sesto et al. (2012), reached similar conclusions.

3.3.3.5 Swabbing

Wacharamanotham et al. (2011) compared two input methods on elderly users with tremor. Tapping was compared to swabbing, i.e., sliding the finger across the screen. Swabbing was slower but had better error rates and higher user satisfaction. Tremor was reduced when the users was sliding the finger across the screen (Wacharamanotham et al., 2011). The study by Wacharamanotham et al. (2011) resulted in two design implications:

- When to choose swabbing: Tapping is a viable choice for square targets that are at least 54 mm wide. When the target width is smaller than 41 mm, swabbing becomes a better alternative.
- Speed-accuracy tradeoff: Elderly users with tremor may prefer a more accurate input method, even if it is slower.

(Wacharamanotham et al., 2011)

3.3.3.6 Tapping vs sliding

Wiegand and Patel (2015) conducted a motor skills assessment study, comparing tapping and sliding tasks using a touchscreen game that involved popping animated balloons by touching them. None of the participants had PD, but all had progressive neurological disorders, with an average age of 56. Wiegand and Patel (2015) concluded, that for optimal performance:

- System functionality should be customizable, binding elements to the top or bottom of the screen can be challenging for many users.
- Users should be able to relocate buttons away from edges and closer to optimal touch areas, reduced performance was observed when users tried to hit targets outside this area.
- Users should be able to toggle swiping and tapping gestures, especially for essential system functionality. Even if sliding to a target is usually slower than tapping, users should not be restricted to using only one of those gestures.

(Wiegand & Patel, 2015)

3.3.4 User interfaces designed for people with PD or people with tremor

3.3.4.1 The Parkinson's tracker app

The *Parkinson's tracker app* for Android and iOS is a self-management and adherence tool to manage PD, where users can enter daily scores on a 5-point scale to measure: water, sleep, exercise, 5 A DAY healthy diet, mood and energy, medication, movement, suppleness and control (Lakshminarayana et al., 2014; Lakshminarayana et al., 2017). For those who had difficulty interacting with the flower icon, an accessibility mode with zoom function to magnify the screen was included.

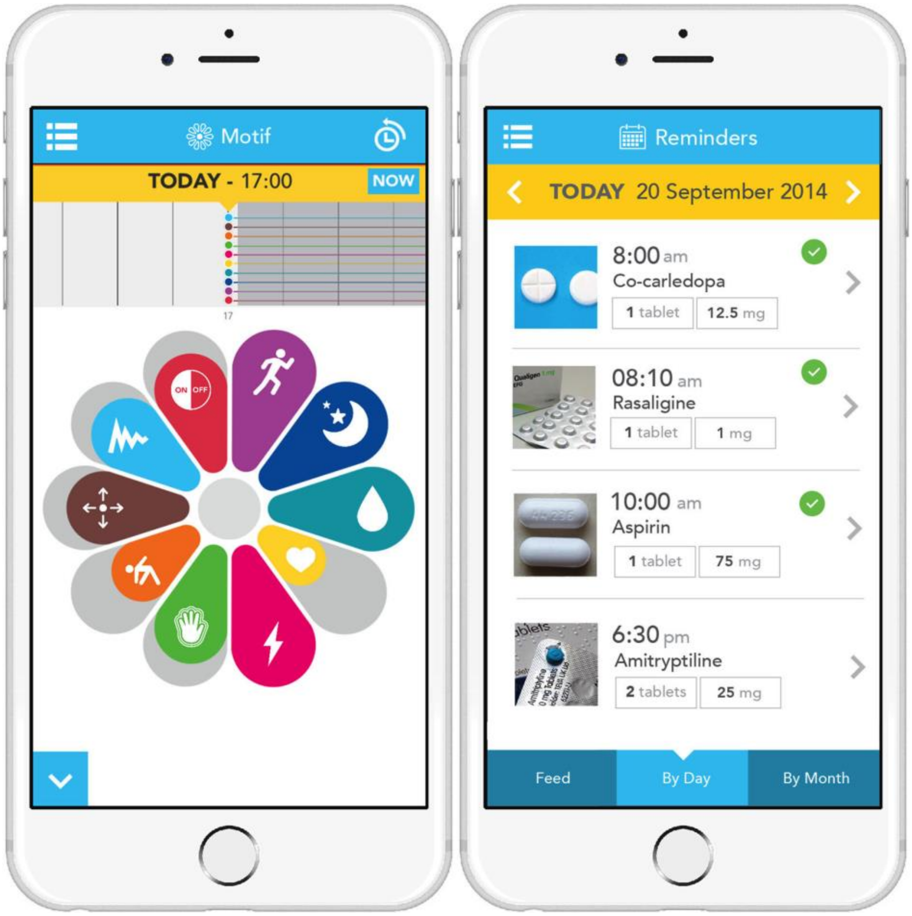

Figure 3.3.1 The Parkinson's tracker app. Left: Self-tracking interface. Right: Reminder interface (Lakshminarayana et al., 2017).

It was used in a study to see if those who used the app showed improved medication adherence compared to those receiving usual treatment. After 16 weeks, the app proved to significantly improve adherence compared to those who received usual treatment.

Participants could review and compare their scores with each other, receive alerts and track medicine intake, they had the option to generate a report detailing the trial period, and to play games to track physical responsiveness.

The app had a higher level of self-reported medication adherence than other smartphone apps, due the design of the user interface and user experience, and because of its simplicity (Lakshminarayana et al., 2017).

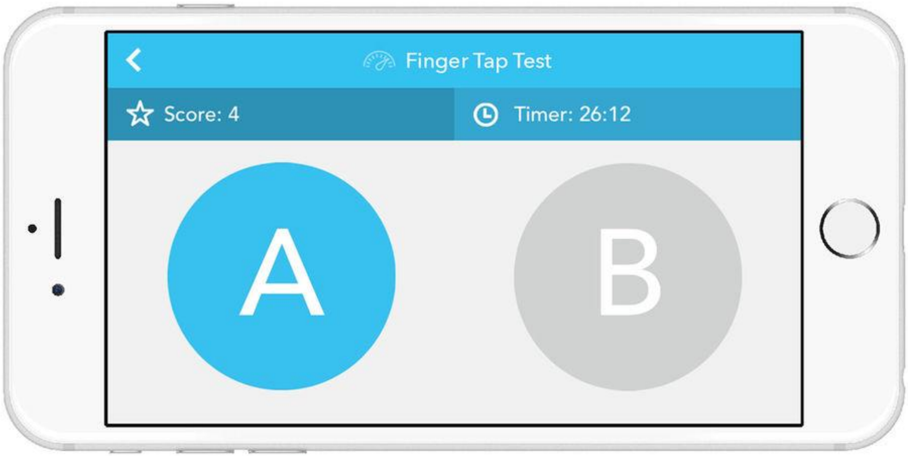

Figure 3.3.2 The Parkinson's tracker app, Finger Tap Test game (Lakshminarayana et al., 2017).

3.3.4.2 The Swabbing Web Browser

Since tremor limits touchscreen input, Wacharamanotham et al. (2013) designed the *Swabbing Web Browser*, operated by swabbing inputs, to study how involuntary tremor influences the use of touchscreens. The browser presents a transparent layer overlaying the webpage, where the user can browse the web using swabbing inputs (Wacharamanotham et al., 2013)

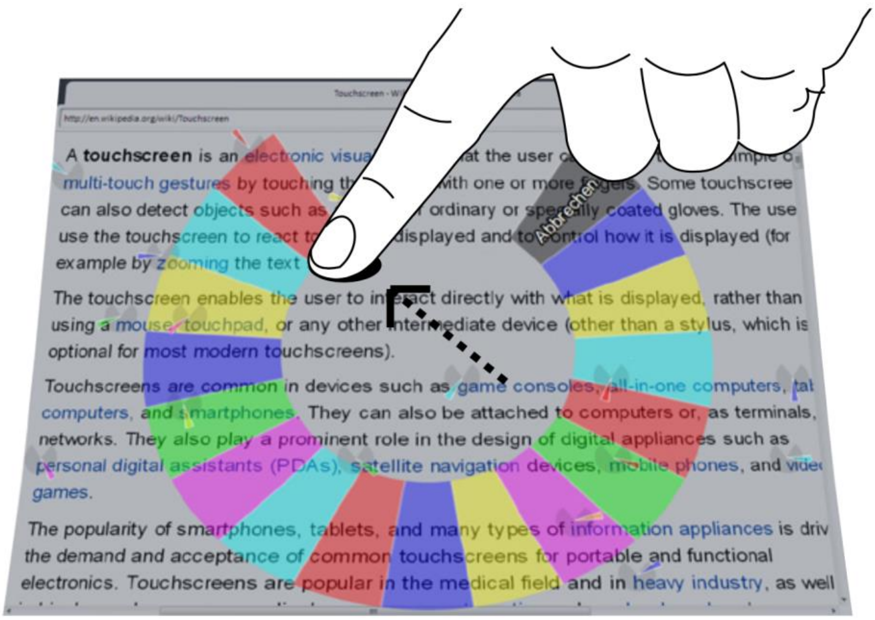

Figure 3.3.3 The Swabbing Web Browser, for users with tremor solely operated by Swabbing (Wacharamanotham et al., 2013).

Following are descriptions of observations made by Wacharamanotham et al. (2013), while observing users interacting with the web browser:

Tapping: Tremor caused participants in the study to deviate from the target and inadvertently "lift-and-land movements on the target, which results in unintentional activations of the target" (Wacharamanotham et al., 2013, p. 2).

Multi-finger tapping: "For users with tremor, a multiple-finger tap recognizer needs an additional spatial threshold to handle jittered and repeated touches. Therefore, designers should maximize the difference in number of touches between two different gestures. E.g., we recommend using one-finger and five-finger tapping when only two gestures are needed" (Wacharamanotham et al., 2013, p. 2).

Sliding: "The jitter from tremor causes fluctuation in sliding; panning with tremor would result in a shaky screen. The jitter also causes the finger to be lifted momentarily from the screen, causing the user to lose the grab of the virtual object in focus or accidentally interact with a nearby object" (Wacharamanotham et al., 2013, p. 2). For input that depends on the touch trace being close to the target to activate, the target must be large (Wacharamanotham et al., 2013).

Multi-finger sliding: Unintentional finger lifting could cause the neighboring traces to exchange association with the fingers, but could be reliability determined by "analyzing the sequence of touch signals over a time window" (Wacharamanotham et al., 2013, p. 2).

3.3.4.3 The mPower study

The Parkinson mPower study app, is an iPhone app used to collect data on users' symptoms and progression as part of a clinical study about PD (Bot et al., 2016). It was developed using Apple's ResearchKit software framework. The user can track their condition daily and share the information with their care team.

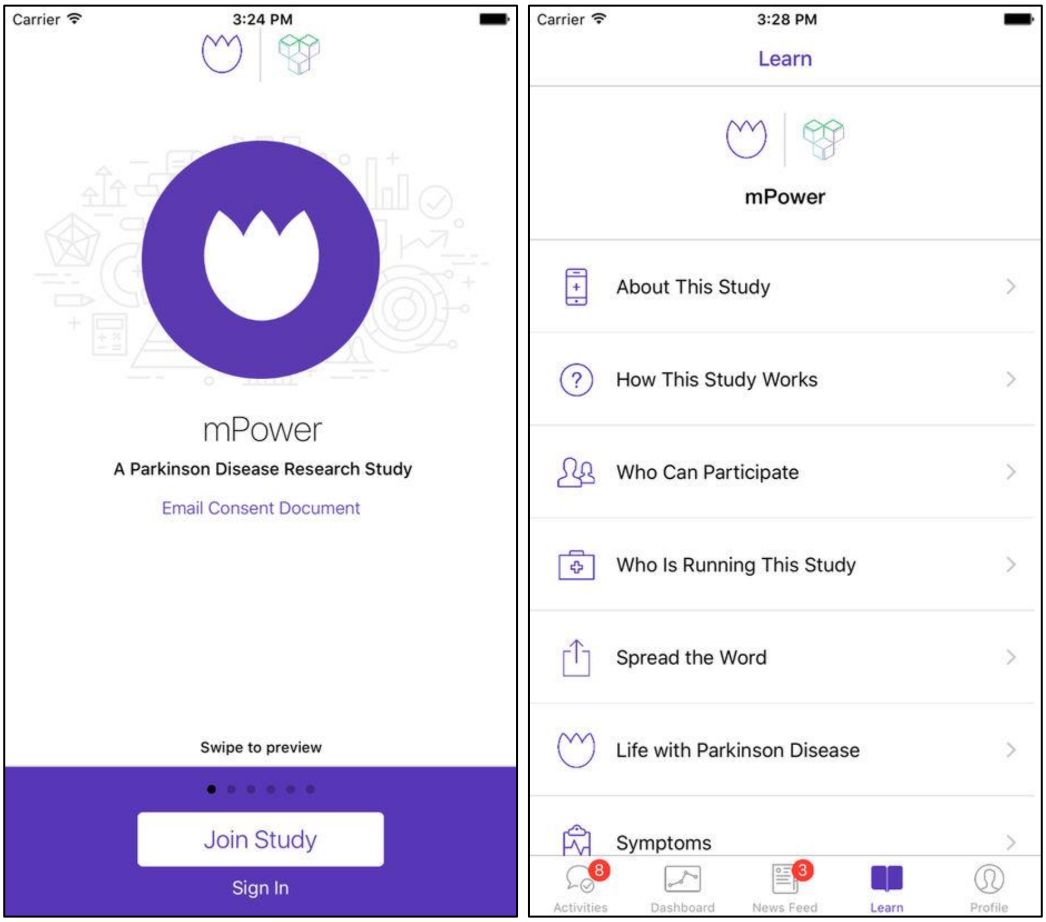

Figure 3.4 Parkinson mPower study app (Sage Bionetworks, 2017).

3.3.5 Guidelines and recommendations

Nunes et al. (2016) investigated how PD influences the interaction with smartphones. They researched relevant literature, interviewed healthcare professionals, observed smartphones users with Parkinson's, and performed a usability study with 39 people with PD. Four gestures were evaluated: tap, swipe, multiple-tap, and drag. In the end, a list of symptoms that influence smartphone interaction was provided, as well as 12 user interface design guidelines for developing smartphone applications for people with PD.

3.3.5.1 User interface design guidelines for smartphone applications for people with Parkinson's disease

Nunes et al. (2016) provides 12 guidelines for designing 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 multiple modalities over a single interaction medium.
12. Consider smartphone design guidelines for older adults (Nunes et al., 2016).

3.3.5.2 Design implications to improve typing accuracy on touchscreens

Nicolau and Jorge (2012) suggest that future mobile interfaces should take users' tremor profile into consideration for a more suitable text-entry design.

Their study resulted in 8 recommendations for text entry design:

- Shift keyboard layout: Elderly benefit from a layout shift in the bottom-right direction.
- Width rather than height: Keys should be wider, rather than taller.
- Narrower spacebar: Smaller spacebar size reduce substitution errors.
- Avoid errors by understanding typing behaviors: Future designs should focus on model users typing patterns by analyzing touch features.
- Allow personalization: Users have individual preferences and differences.
- Deal with poor aiming rather than finger slips: Finger slips are only a small fraction of substitution errors.
- Use language-based correctors: Simple language-based solutions are suitable for elderly users, as cognitive errors are common.
- Compensate hand tremor: There is a large correlation between tremor and input accuracy. The user's tremor profile should be used to compensate typing errors. (Nicolau & Jorge, 2012)

4 Research Approach and Methodology

The development process of the exercise app will follow a user-centered design approach. This section describes principles and methods used during this process.

4.1 User-Centered Design

Since the app is being created for people with PD, the end-users should be included in the design process. Therefore, the principles of user-centered design which details user involvement when designing ICT solutions, will be followed.

"User-centered design (UCD) is an approach that involves end-users throughout the development process so that technology support tasks, are easy to operate, and are of value to users" (De Vito Dabbs et al., 2009, p. 1). Because users are involved, the developers avoid making assumptions based on wrong preconceptions, e.g., by not using stereotypes.

Several of the papers mentioned in the literature review involved users with PD or tremor in the design process. Barros et al. (2013) found a UCD approach to be efficient in the creation of smartphone applications, and McNaney et al. (2015) mentioned the importance of involving users in the development of their exergames.

4.1.1 Human-centered design for interactive systems

ISO 9241-210:2010*, Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems*, provides a framework for human-centered design.

It is a central standard of UCD, where *human* is used instead of *user* to emphasize that it addresses several stakeholders, not only those considered typical users of a system (Fuglerud, 2014).

This standard includes "requirements and recommendations for human-centered design principles and activities throughout the life cycle of computer-based interactive systems" (ISO, 2009, p. 1).

4.1.1.1 Why adopt a human-centered design?

A highly usable system is more successful, both technically and commercially (ISO, 2009). An easy to use and understandable system lessens the need for support, which saves time for users, as well as time and money for those providing support (ISO, 2009). In most countries, it is required by law for employers and suppliers to protect its users from health risks, and by using human-centered methods this can be reduced (ISO, 2009). Examples of how human-centered design improve quality, from ISO 9241-210:2010:

- Increasing the productivity of users and the operational efficiency of organizations.
- Being easier to understand and use, thus reducing training and support costs.
- Increasing usability for people with a wider range of capabilities and thus increasing accessibility.
- Improving user experience.
- Reducing discomfort and stress.
- Providing a competitive advantage, for example improving brand image.
- Contributing towards sustainability objectives (ISO, 2009).

To see the complete benefit of adopting a human-centered design, one have to take into account all the costs during the life cycle of a product, service, or system, "including conception, design, implementation, support, use, maintenance, and finally, disposal" (ISO, 2009, p. 4).

A human-centered approach also benefits other aspects of system design, such as improving the "identification and definition of functional requirements" (ISO, 2009, p. 4).

4.1.1.2 Principles of human-centered design

According to the standard, a human-centered design approach should include the following principles:

- The design is based upon an explicit understanding of users, tasks and environments.
- Users are involved throughout design and development.
- The design is driven and refined by user-centered evaluation.
- The process is iterative.
- The design addresses the whole user experience.
- The design team includes multidisciplinary skills and perspectives (ISO, 2009).

4.1.1.3 Human-centered design activities

The human-centered design process can be illustrated as a circular, iterative process (see Figure 5.1). It does not have to be a strict linear process. Each human-centered design activity uses outputs from the other activities (ISO, 2009).

According to Fuglerud (2014), this process has six main activities:

1. Plan the human-centered design process.
2. Understand and specify the context of use.
3. Specify user and organizational requirements.
4. Produce design solutions.
5. Evaluate design against requirements.
6. ICT solution that meets user requirements (Fuglerud, 2014; ISO, 2009).

Activity 2-5 should be repeated as many times as necessary, until the system has the appropriate quality and meets the user requirements (Fuglerud, 2014).

These activities can also be used on a lower scale, as they can be used to obtain feedback on early design concepts, before finalizing requirements (ISO, 2009). By evaluating rough prototypes and mock-ups of potential designs, a deeper understanding of user needs can be obtained (ISO, 2009).

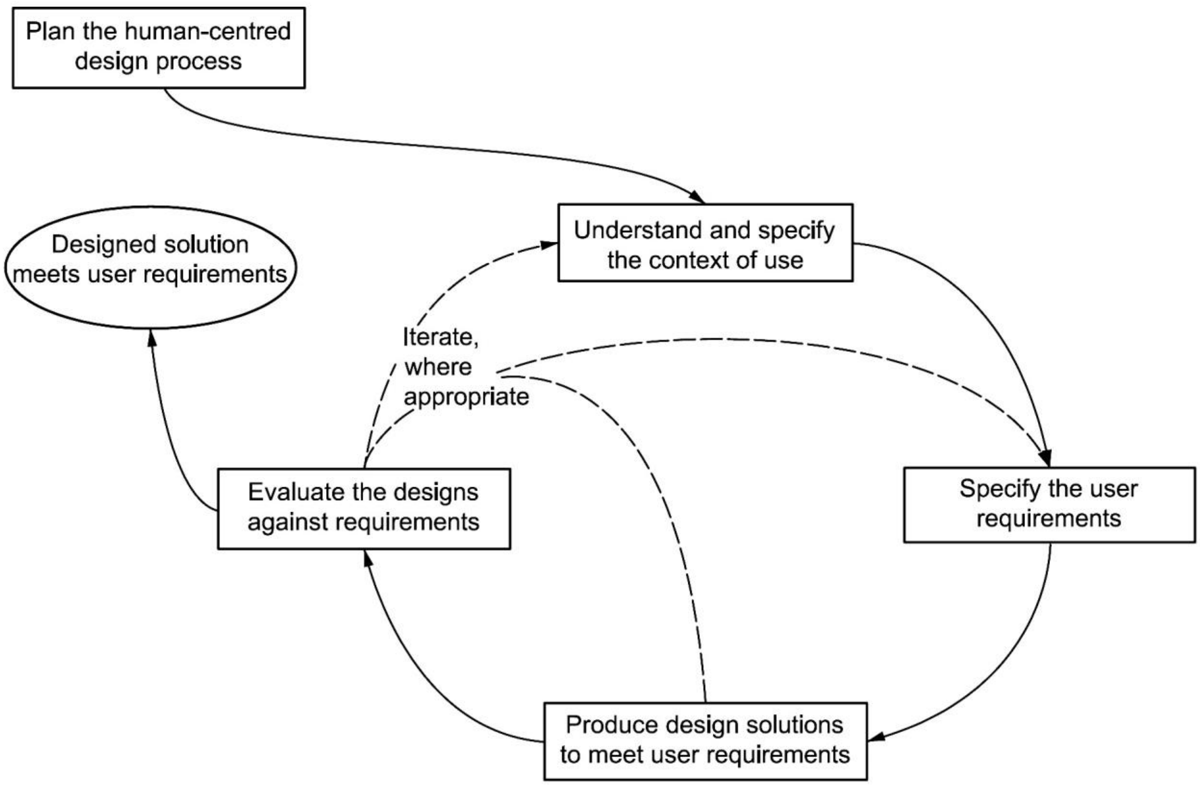

Figure 4.1 Interdependence of human-centered design design activities (ISO, 2009).

4.2 Evaluation and Data Collection Methods

Following is a description of the methods I will use to evaluate the design of my exercise app.

4.2.1 User Testing

The most important tool for evaluating usability is user testing with representative users. It provides direct information, from real users, about the interaction with the user interface, and helps with finding exact problems (Jakob Nielsen, 1994b).

To find what to measure during user testing, it is important to listen to the what the users say when evaluating the prototype. This can help identify measureable usability criteria (Abras, Maloney-Krichmar, & Preece, 2004). "Measurable usability criteria address issues related to the effectiveness, efficiency, safety, utility, learnability and memorability (how long it takes to remember to perform the most common tasks) of the product/artifact and users' subjective satisfaction with it" (Abras et al., 2004, p. 5).

4.2.2 Heuristic evaluation

A heuristic evaluation is done by looking at an interface while trying to find what is good and bad about the design (Jakob Nielsen, 1994b). The goal is to find usability problems in the user interface design, and can be applied in an iterative design process (Jakob Nielsen, 1994b). This can be done by evaluating the design against guidelines or by using online tools. Heuristic evaluation differs from user testing by placing responsibility for finding issues solely on the evaluator (Jakob Nielsen, 1994b).

According to Jakob Nielsen (1994b), most people do this by using their own intuition and common sense, but it can be difficult for a single person to find most usability problems. By having more than one evaluator, the chance for finding problems increases (Jakob Nielsen, 1994b).

4.2.3 Observation

By observing the user, it is possible to see and understand where in the interface they encounter problems (Lazar, Feng, & Hochheiser, 2017).

One observation method is to sit next to the user while they perform a task. This may cause the user to feel uncomfortable and they may act differently than if they were alone (Lazar et al., 2017). Lazar et al. (2017) suggest using a portable observation laboratory with cameras, microphones, and recording devices. By doing this, the observer does not have to sit right next to the user.

4.2.4 Thinking aloud

In the thinking aloud method, first introduced in human-computer-interaction (HCI) by C. Lewis and Mack (1982), the user is instructed to say aloud what they are doing, thinking, and feeling while conducting tasks (Fuglerud, 2014). It gives instant results, and is effective due to the need for few test subjects (Janni Nielsen, Clemmensen, & Yssing, 2002).

During the user test, the observer sits next to the participant, and watch and listen. If the user becomes silent, the observer prompts the participant to think aloud again (Fuglerud, 2014).

"The strengths of this method are that it may give very detailed information about what parts of the user interface cause problems and why the problems occur, with relatively few participants and without the need for special equipment" (Fuglerud, 2014, p. 78)

A weakness of the method, is that some users may experience trouble speaking, due to cognitive load and added strain when a task becomes demanding (Janni Nielsen et al., 2002).

4.2.5 Interviews and focus group

By interviewing users, it is possible to explore a wide range of concerns about a problem, since the interviewee is given the freedom to provide detailed responses (Lazar et al., 2017). It is possible to gather data that otherwise would be difficult to acquire: "Given a chance to answer questions that encourage reflection and consideration, interviewees may go on at great length, generating ideas and sharing insights that would have been lost to surveys" (Lazar et al., 2017).

Direct discussions with participants is usually done in one of two ways: interviews with a single person and focus groups involving multiple users at the same time (Lazar et al., 2017). Interviews can be flexible, open-ended, and exploratory. Follow up questions can be based on previous answers, and new directions can be explored on the fly (Lazar et al., 2017).

Analysis can be difficult, to select what is useful and what is not can take a long time. It can be a challenge to separate the good data from the bad (Lazar et al., 2017). To combat this, Lazar et al. (2017) recommends combining interviews with observation of users. By observing the user first, it is possible to ask questions related to problems encountered while performing a task.

It can also be helpful to use aids when interviewing. Jacob and Furgerson (2012) have written a guide for students that details how to create successful interview protocols for use in qualitative interviewing. The guide details the whole process: what to do before, during, and after the interview. Some of the recommendation is to use a script, use open ended questions, and to “close your mouth and listen!” (Jacob & Furgerson, 2012, p. 9).

4.3 User Experience

“User experience focuses on the user’s preferences, perceptions, emotions and physical and psychological responses that occur before, during and after use, rather than the observed effectiveness and efficiency” Bevan, Carter, and Harker (2015, p. 149). While user experience is about individual goals, usability focuses on goals shared by a user group (Bevan et al., 2015). Before focusing on the user experience, the system must be accessible and usable.

4.3.1 Accessibility

Accessibility essentially means that a product can be used by people with disabilities (Henry, 2007). It is what makes a user interface perceivable, operable, and understandable for people with a wide range of abilities, and it encompasses all disabilities or functional limitations (Henry, 2007).

ISO 9241-11 offers a basis for specifying and evaluating accessibility by looking at effectiveness, efficiency, and satisfaction for a wider range of user capabilities (Bevan et al., 2015). Accessibility can be interpreted as usability for people with the widest range of capabilities (Bevan et al., 2015; International Standardization Organization (ISO), 1998).

Accessibility is also what makes products usable in a wide range of situations, contexts, and environments (Henry, 2007). Situational limitations can affect everyone, not only those with a disability, e.g., using a smartphone in direct sunlight, or sending text messages by using your voice when driving a car.

It is therefore important to conduct a thorough accessibility evaluation, early and often, throughout the development process. An accessibility evaluation is usually done by assessing conformance to accessibility standards (Henry, 2007).

4.3.2 Usability

Usability is defined by ISO 9241-11 as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO, 1998).

To specify or measure usability, it is necessary to “identify the goals and to decompose effectiveness, efficiency and satisfaction and the components of the context of use into sub-components with measurable and verifiable attributes” (Bevan et al., 2015, p. 144).

J. R. Lewis (2006) mentions two main ideas of usability testing: measurements related to the accomplishment of global task goals (summative, or measurement-based, evaluation), and detection and elimination of usability problems (formative, or diagnostic, evaluation).

Usability testing involves representative users attempting representative tasks in representative environments (Lazar et al., 2017; J. R. Lewis, 2006) It can be used to obtain quantitative and qualitative data from real users performing real tasks when using a product (Henry, 2007). Metrics used should include measurement of task performance and time performance (Lazar et al., 2017).

All this can help with evaluating how accessible a system is to people with disabilities, by observing the users while they perform tasks and discussing accessibility issues they encountered (Henry, 2007).

Usability testing should be done after accessibility testing, since some parts of accessibility testing is possible to conduct without including users, e.g., testing conformance to standards. Since user testing is usually more time consuming and expensive, it is best to remove as many barriers as possible before including real users.

4.3.2.1 Nielsen’s 10 usability heuristics

Jakob Nielsen (1994a) presented, among several usability guidelines, 10 general principles for interaction design to be used in a heuristic analysis. Presented here is an updated version (Jakob Nielsen, 2005).

- Visibility of system status.

Users should always know what is going on within the system by receiving suitable feedback within a reasonable time (Jakob Nielsen, 2005).

- Match between system and the real world.

The system must be understandable to the user, it should speak the users’ language. Familiar words, phrases and concepts should be used, and not system-oriented terms that can be difficult to understand (Jakob Nielsen, 2005). Familiar conventions from the real world should be followed, with information appearing in a natural and logical order (Jakob Nielsen, 2005).

- User control and freedom.

The user should easily be able to rectify a mistake. An “emergency exit” should be easy to find and use in case of mistakes by the user (Jakob Nielsen, 2005). Undo and redo functions are examples of this that should be supported.

- Consistency and standards.

Platform conventions and standards should be followed to avoid confusing the user. “Users should not have to wonder whether different words, situations, or actions mean the same thing” (Jakob Nielsen, 1994a, p. 156).

- Error prevention.

Preventing problems from happening in the first place is better than showing an error message after. Error-prone conditions should be removed or be presented clearly to the users with the option to confirm before committing to an action (Jakob Nielsen, 1994a).

- Recognition rather than recall.

Objects, actions, and options should be visible to minimize the users’ memory load (Jakob Nielsen, 2005). How to use the system should be clearly visible or easily retrievable. It should not be up to the user to remember from one part of the dialogue to another (Jakob Nielsen, 2005).

- Flexibility and efficiency of use.

Systems should cater to both experienced and inexperienced users, and also allow for the option to tailor frequent actions (Jakob Nielsen, 2005). For expert users of a system, Jakob Nielsen (2005) recommends the use of accelerators, unseen by the novice users, to speed up interaction.

- Aesthetic and minimalist design.

Irrelevant or rarely needed information should not be shown in dialogues. Unneeded information contributes to cluttering of the interface, and diminishes the visibility of relevant information (Jakob Nielsen, 2005).

- Help users recognize, diagnose, and recover from errors.

Error messages should be easy to understand and not presented to the user with codes (Jakob Nielsen, 2005). The problem should be precisely indicated, and a constructive solution suggested (Jakob Nielsen, 2005).

- Help and documentation.

Even if a system can be used without help and documentation, it should still be provided. “Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large” (Jakob Nielsen, 2005, p. 1).

4.3.3 Universal design

Universal design (UD) is defined as “the design of products and environments to be usable by all people, to the greatest extent possible, without adaptation or specialized design” (The Center for Universal Design, 1997). Use of the term began in the 1970s at the Center for Accessible Housing at North Carolina State University (Null, 2013). Ronald L. Mace(1942-1998), the director of the Center, was UD’s earliest and most important promotor (Null, 2013).

The design should be accessible and usable to as many people as possible. When a product is made more accessible to people with disabilities, it is at the same time made more accessible to everybody (Fuglerud, 2014; The Center for Universal Design, 1997).

To guide the design of environments, products, and communications, the Center for Universal Design at North Carolina State University has created the following seven principles for UD:

1. Equitable use.
2. Flexibility in use.
3. Simple and intuitive.
4. Perceptible information.
5. Tolerance for error.
6. Low physical effort.
7. Size and space for approach and use (The Center for Universal Design, 1997).

Each principle has a set of guidelines that can be applied to both the physical and digital world.

A universally designed product is accessible and usable to as many people as possible, and the best way to ensure this is to involve users in all parts of the development.

4.4 Data Collection Methods for Collecting Data From Older Adults

The majority of people with PD are elderly, therefore, the methods chosen when collecting data should be those best suited for that age group. Sujan Samuel Roy, Neumann, and Fels (2016, p. 188) conducted a literature review of 41 research articles aimed at assessing the application of basic UCD methods with older adults. The methods analyzed was: questionnaires, focus groups, cultural probes, diary studies, the think aloud protocol, interviews, and paper prototyping. Of those, only the think aloud method, culture probe, and paper prototyping were used in the development of technology or devices.

Paper prototypes and cultural probes were used to find typical user needs, diary study helped understand the behavior of individuals, while interviews tended to result in less valuable data in terms of user needs (Sujan Samuel Roy et al., 2016).

The thinking aloud method highlights problems faced by the user while performing a task or process (Sujan Samuel Roy et al., 2016). This was mentioned earlier, and is confirmed by Sujan Samuel Roy et al. (2016) in their review. For some elderly, the dual task of thinking aloud while at the same time performing a task caused poor performance, possibly due to limited motor or cognitive abilities (Sujan Samuel Roy et al., 2016).

Culture probes and diary studies can be used to more efficiently design assistive technology or products for users with intermittent memory loss or dementia (Sujan Samuel Roy et al., 2016). Focus groups benefits from creating an interaction between the moderator and the participants, and even tough it is time consuming, it can be used to identify user needs (Sujan Samuel Roy et al., 2016).

Observational methods can be used to help designers understand problems and concerns, but lead to less information about the user experience (Sujan Samuel Roy et al., 2016). None of the papers analyzed used questionnaires as a primary tool to gather user requirements, it was used mostly for gathering info about the users (Sujan Samuel Roy et al., 2016).

Sujan Samuel Roy et al. (2016) ends their literature review by concluding that there is a need for new approach when collecting data from elderly, that builds upon the existing conventional methods. These methods must be enhanced to give people with cognitive disabilities a voice (Sujan Samuel Roy et al., 2016).

Elderly should “be given the opportunity convey their issues, how it affects their daily life and express the need to address the problem by means of inclusive design and assistive technology development” (Sujan Samuel Roy et al., 2016, p. 469).

4.5 Ethical Considerations

When users are involved, they must be treated with respect. They must be informed about the study they are involved in so they can make a meaningful decision to participate or not (Lazar et al., 2017). They must give informed consent.

Informed means that the participant understands the reason for the study, procedures, risks, and how to get more information about the study (Lazar et al., 2017). About *consent*, Lazar et al. (2017) states that the involvement should be voluntary and free from coercion.

Some people with disabilities may be used to being tested regarding their own impairments. Therefore, before the testing, it is important to inform the participants that it is the design that is being tested and not the users themselves (Lazar et al., 2017). They are helping to improve the design.

4.6 Summary of Research Methodology

To create a foundation for an optimal user experience, a product must be accessible and usable. Usability is about how easy it is for users to achieve their goal when using a product. For this to be achievable, it must be accessible. As many as possible must be able to access the product, including people with disabilities. It must also be usable in diverse situations and environments.

Universal design is a philosophy which states that the design of products and environments should be usable by all people “to the greatest extent possible, without the need for adaptation or specialized design” (The Center for Universal Design, 1997)

While universal design encompasses all parts of our daily lives, user-centered design focuses on the development process of ICT solutions. It is an approach that describes how to include users in the design process. This contributes to accessible and usable solutions. ISO 9241-210 is a standard that describes this process in detail for interactive systems. The process should be based on an explicit understanding of users, tasks, and environments. Users should be included in all stages of development, and the process should be iterative.

For the design and development process, user-centered design was the main guiding methodology. The initial requirements were first gathered through a literature review, an interview with a physiotherapist, and a focus group interview with people with PD. Based on this a prototype was designed and developed.

When evaluating the user interface during development, there are several tools that can be used. User testing helps with finding problems encountered by real users, while heuristic evaluation is based on the evaluators own experience and against guidelines. Both methods are useful, and a combination of them was used in the development of the exercise app prototype. It is also important to obtain informed consent from the participating users.

It is important to give participants enough information for them to be able to make an informed decision about participation in the user testing. Participants was be given a consent form to sign with details of the testing, including how the results will be stored and used. The users' names will be kept confidential, and it will not be possible to identify them when reading the final report.

Three iterations of the prototype were made. In each iteration, data collection methods such as observations, thinking aloud, focus groups, and interviews was be used. The universal design principles and usability heuristics guided the activities in each of the iterations.

5 Design and Development

This chapter describes the design and development process of the exercise prototype. The process was user-centered and started with gathering requirements based on the literature review, then was followed up by interviews with a physiotherapist, people with PD, and health care workers. After the finding requirements, 3 iterations of prototypes were made, with each iteration being evaluated by users, health care personnel, or both.

5.1 User Requirements

The initial requirements for the app were based on the literature review, an interview with a physiotherapist working with people with PD, and focus group interviews with people with PD and health care workers.

5.1.1 Interview with a Physiotherapist Working with People with PD

The physiotherapist teaches users at rehabilitation center for people with PD. She makes sure that the users are taught the correct exercises they need to maintain their physical abilities while living with PD. Exercise does not stop the progression of the disease, but together with medication it can help the patient continue living a normal life as long as possible.

When the users leave the rehabilitation center they receive an individual exercise plan to follow when they go back home. She mentioned that instead of giving users exercises on paper, they could help the user set up the app during their stay at the rehabilitation center.

Many of their users struggle with following the exercise plan after going back home. In many places there is not always a physiotherapist or personal trainer that is knowledgeable enough about PD to make sure the correct exercises are performed. Being reminded by notifications and having the exercise plan in an app can help with this.

It is important that the patients have a goal to work towards. It helps with motivation. The goals can vary from patient to patient. Some have more severe symptoms and just want to be able to perform normal daily activities. Others have more common exercise goals. Examples mentioned varied from running a half-marathon to being able to walk out to pick up the mail.

After showing the initial mockup prototype to the physiotherapist, she had some suggestions for features that should be included. Since the recommended exercises varies from user to user, it was suggested that the user should have the possibility to add exercises themselves together with video, image, and text instructions. This can also be done by a health care professional when helping the user set up the app for first time use. This way, the user can add their personally recommended exercises. There already exists many exercise guides and videos online for people with PD that can be used. It was also suggested that the user could film themselves while receiving exercise instructions, making it possible to have a detailed personal exercise guide.

The app should let the user set goals to work towards. This helps with the motivation to exercise. It is also important that the user have taken their medication a little while before exercising, she suggested that the app remind the user to take their medication 30 minutes before the exercise. If the user exercise when they are not in the right condition it might be detrimental and not give the positive effects that exercising usually gives.

Another idea was including the option to add contact info to health care personnel, such as the user's doctor, physiotherapist, and other people they might want to contact when needing personal help related to exercising. This is also an option included in several existing medication reminder apps.

By having medical contact info and medication intake reminders included as features in the exercise app, the need for having several other apps is reduced. It should be optional for the user to use these features, but the ease of having everything needed in one app is convenient.

5.1.2 Focus Group with People with PD

A focus group interview was conducted to gather needs and requirements directly from users. It included 20 people with PD in various stages of the disease. Half of them used touch devices in their daily lives. All participants where above the age of 60. The focus group was conducted at the same rehabilitation center as were the previously interviewed physiotherapist worked. Their focus is on Parkinson Wellness Recovery, a method based on research and knowledge about exercise and movement as a defense against PD.

At the rehabilitation center users with PD are taught about how to live with the disease. Among other things, they are taught exercises that have a positive effect on symptoms and the progression of PD. Many of the users struggle with continuing to exercise after their stay at the rehabilitation center. There can be several reasons for this. Many do not have the same guidance and supervision in their local community as they have at the rehabilitation center, while others struggle to motivate themselves to exercise on their own.

During the focus group, these needs and requirements were collected:

- The app must be simple, and not have too many features.
- The app should focus on the most important features.
- Include contact information to people the user may need to contact in case they have questions or need help with exercising.
- Have a database of exercises to choose from.
- Add about 8-10 exercises in a daily exercise plan.
- Be able to scroll down and choose exercises.
- Repeat the plan for the rest of the week.
- Be able to remove and replace individual exercises from the plan.
- Ability to add video guides to the exercises. Either by adding a link to an online video or by providing the video themselves.
- It is easier to use a tablet than a smartphone. It has more space, and the larger screen makes it easier to watch videos of exercises.
- A medicine reminder.

The users also mentioned other features they wanted not related to exercising, such as links to local PD organizations, Facebook groups, and general information about PD.

5.1.3 Focus Group with Health Care Workers

A shorter interview was conducted with a group of 7 health care workers. The importance of exercise and medication was repeated. It was also reiterated that the app must be simple to use

One of the health care workers mentioned that an app would be a good way for users to self-report on/off-symptoms instead of having to fill out a paper form several times each day. For some it is stressful to remember to do this and to keep track of where they left the form after previous use. This stress can affect the measurements, so an app may help the user with this.

5.1.4 Summary of User Requirements

After the interviews and focus group, the main features of the exercise app were decided:

- Remind the user to exercise.
- Motivate the user to exercise.

- Show the user how to perform the exercises.
- The user is able to confirm that the exercise has been performed.
- Create an exercise plan.
- Set exercise goals.
- Remind the user to take their medicine.
- Give the user an option to add contact info to add contact info to health care personnel.

5.2 First Prototype

The development of the first prototype began based on the literature review. It had the start screen and buttons to the various features, see Figure 5.1. After the interview with the physiotherapist working with people with PD, it was updated based on her feedback. Adding goals and contact persons were added as options.

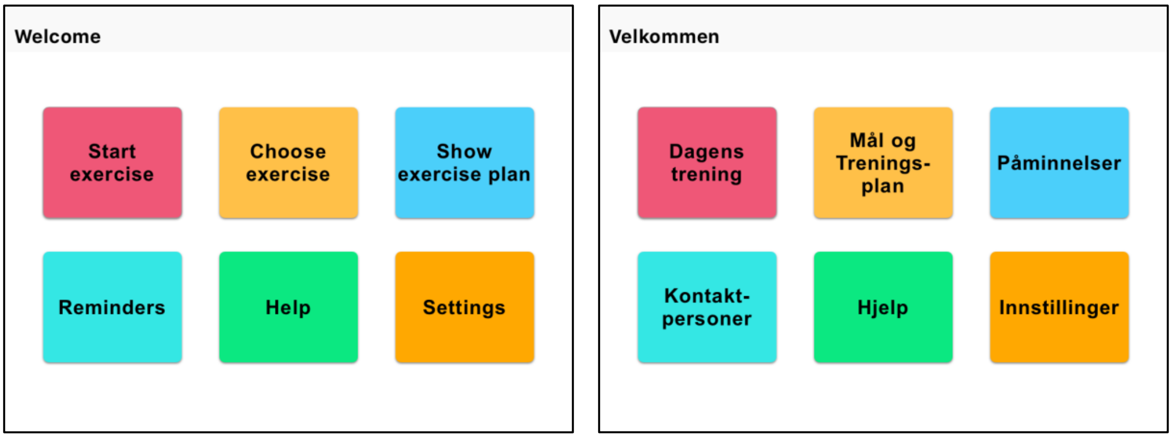

Figure 5.1 Mockup of the start screen in the first prototype. First version on the left, updated version on the right.

5.2.1 Implementation

The prototype was made with Apple's Xcode and coded mostly in Swift with some parts in Objective-C.

5.2.1.1 The Start Screen

To keep the start screen simple and to avoid too much information when opening the app, it was decided to just have a few large buttons that leads to the main functions: Start exercise, create exercise, show exercise plan, contact persons, help, and settings.

- Start exercise will start the exercises program and show the first exercise. When the user has confirmed that an exercise is complete, the next exercise in the program will show.
- Create exercise lets the user create exercises and add them to the database. The user can enter text in the following fields when creating an exercise: Title, link to video, add pictures, exercise description.
- Show exercise plan has a calendar with overview of each day's scheduled exercises, as well as the options to add and remove exercises to the plan.
- Set reminders have options for when to be reminded, e.g., how long before the exercise starts, how many reminders for each exercise session, or the option to turn all notifications off.
- Help will have a detailed description of all the functions, with pictures describing how to use the app.
- Setting will have accessibility options to change text size and color, and let the user turn on/off all the app's notifications.

Several of these were changed in later prototypes.

5.2.1.2 Navigation

To make navigation simple, access to functions will use as few clicks as possible from the start screen. For the initial prototype, each of the six main functions can only be accessed from the main screen. To go from one to another, the user must first go back to the main menu. This avoid cluttering each screen with extra options and menu items.

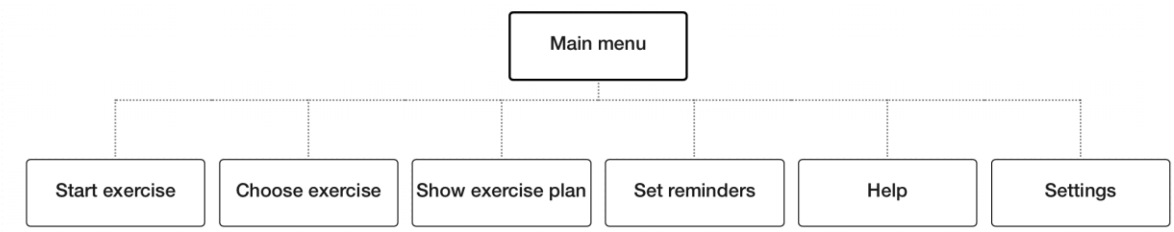

Figure 5.2 Hierarchical overview of the first prototype

At all times, the title at the top of the app will show the user where they are in the app. The title of the current view will be easy to see, along with a button to go back to the previous screen.

Figure 5.3 Example showing the navigation bar.

5.2.1.3 Fonts

The font type used is the standard iOS font. According to Apple (2018b) this font is optimized to give text "unmatched legibility, clarity, and consistency" (Apple, 2018b). Font size will follow guidelines from the literature review, and the user will be able to change size in the settings menu. In later prototypes the font size was made to follow the user's settings in iOS.

5.2.1.4 Buttons

Buttons and tap targets will have a minimum size of 14 mm on each side. Button appearance will follow the system convention for buttons. In iOS this means that the button will have blue text with no outline. Red color will be used for buttons that deletes or removes items, also commonly used in iOS.

5.2.1.5 Colors and contrast

The app will not rely only on colors to convey information to the user. High contrasting colors will be used for the buttons on the start screen with black text. In addition, there will be options for several different color combinations based on user preference to support users with color blindness. Due to iOS having several different color filters to support users with color blindness, this was never coded into the prototype.

5.2.2 Feedback from users

Since it can be difficult for users with little ICT experience to imagine a new system, a simple prototype can be helpful when trying to come up with ideas, and the first protoype was very simple. Many features were not fully working, but the interface did not show this. To the user it seemed as if the app was close to being finished.

The app was shown to a group of 5 users with PD. The features were explained in detail and the users was told to voice their opinion while navigating inside the app.

They liked that the fact that it was on a tablet, saying that the smartphone screen sometimes is too small. The contrast and color were also good. Dark text on light background, as used in the prototype, was preferred.

When exercising they all agreed it would be useful to have a series of pictures or a video of the exercise in addition to text descriptions.

One user mentioned that he would like to be able to rate each exercise after having tried them. This would make it easier to find suitable exercises when setting up a new exercise plan. When asked if a five-star rating system would be suitable, all five agreed that they wanted something simpler. One suggestion was three ratings: easy, okay, hard. Another was: bad, okay, good.

When asked if writing your own comments for an exercise was something that should be added, it was agreed on that it would be too much for many users. It is important that the app is simple and do not become too complicated for most users.

A user said he would like to have pre-made exercise plans based on different muscle groups or exercise categories. Another mentioned that is would be useful to be able to categorize individual exercises to make it easier to find and add desired exercises to a plan.

Being able to see exercise your own exercise history could help with motivation. One user said if he could see that he had been easing off on his exercising in the last few weeks, it would motivate him to increase his performance.

A new field for adding contact persons were found. Name, title, e-mail, and phone number was previously the only info stored. After a discussion it was decided that another field where the user could enter the contact persons available hours was a good idea, such as a doctor's opening hours or when a personal trainer is available for answering a call.

A couple of users said it would be useful to see the estimated duration for each exercise and show total duration time for exercise plans.

5.2.2.1 Heuristic evaluation

After reviewing exercises suited for people with PD it was found that there was a need for adding additional information when creating exercises in the app. Some exercises have a warning that there is a possibility of falling if not precautions are taken when performing the exercise. Other times there is a need for extra equipment. Therefore, a field for entering additional info when creating an exercise was added and will be shown above the exercise instructions.

5.3 Second Prototype

The second prototype focused on improving the accessibility by adding support for Apple's accessibility settings in iOS

5.3.1 Implementation

Since the accessibility features planned to be included in the app was already supported in Apples accessibility settings in iOS, it was decided to make sure the code followed Apple's recommendations.

5.3.1.1 iOS Accessibility Settings

Apple has native support for many accessibility features, such as adjustable font sizes, bold text, marking buttons more clearly, increased contrast and colors, inverted colors, and color filters for various types of color blindness.

By adding support for Dynamic Type and using scalable font sizes, the font is scaled according to the user's preference set in the iOS Accessibility Settings (Apple, 2018a). In the code priority can be given to elements so that when the font size is enlarged, the most important elements become larger first. One example from the app is when viewing contact persons: the phone number and e-mail address are prioritized, and if the e-mail address is long the e-mail label is removed to give more space to the e-mail address. See figure 5.4.

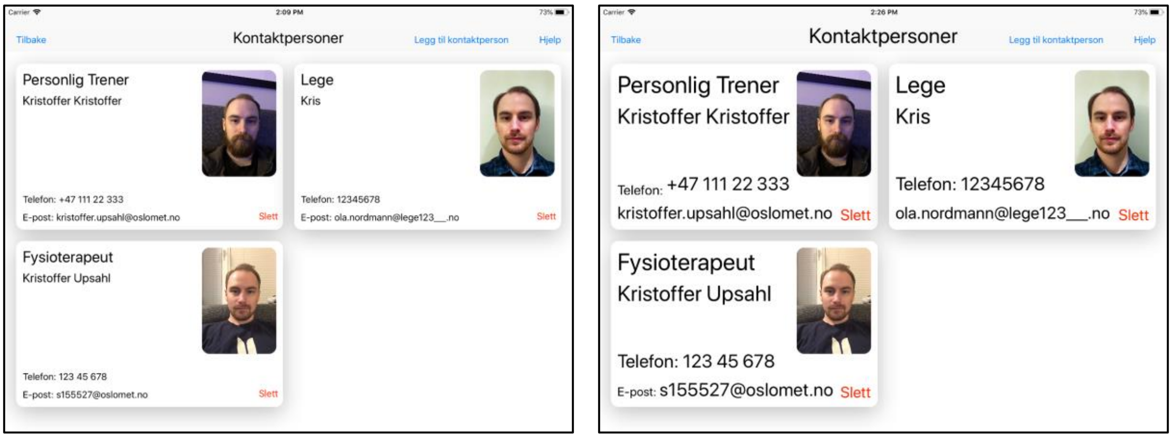

Figure 5.4 Contact Persons screen. Left: Normal font size. Right: Large font size.

Buttons can be made more visible by enabling Button Shapes. This gives button an underline similar to hyperlinks on the web. See figure 5.5

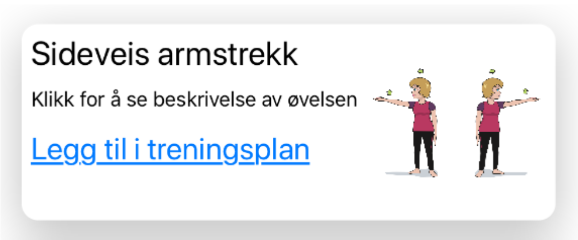

Figure 5.5 Button with Button Shapes enabled.

Other iOS accessibility features include bolder text, options for increased contrast and colors, inverted colors, and color filters for various types of color blindness

In the prototype, explanation for how to enable these features can be explained in the settings and help section.

5.3.1.2 Color Contrast

W3C describes how WCAG 2.0 and other W3C/WAI Guidelines apply to mobile (W3C, 2015). To be in conformance to the AAA level, the contrast ratio must be atleast 7. By using the Color Contrast Checker made by WebAIM (2018) it at was discovered that the contrast between the black font and the red button on the start screen was 6.30:1. Therefore the color was changed to a brighter red with a 8.10:1 contrast to black. The five other start screen buttons had a contrast above 11:1.

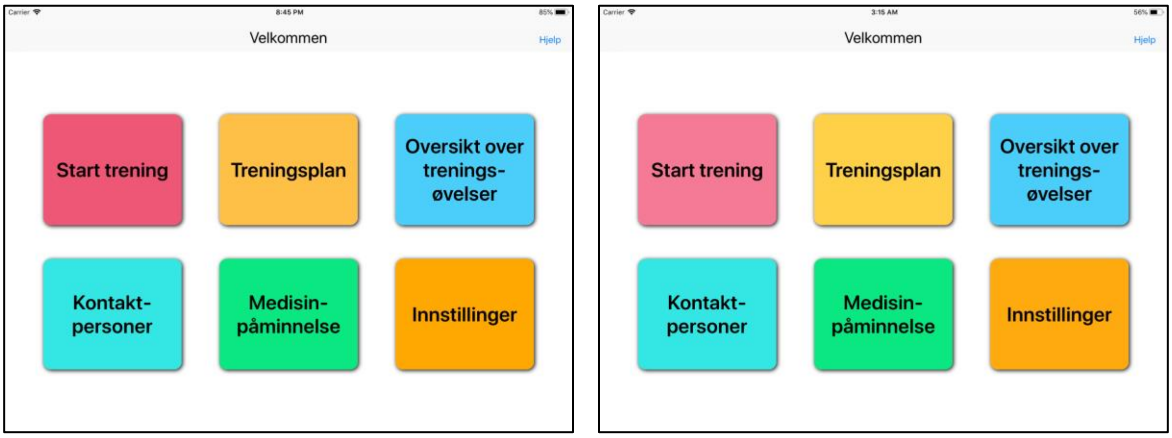

Figure 5.6 Start screen before (left) and after (right) improving contrast on buttons.

5.3.2 Feedback from users

User testing was done with 3 people with PD, one male and two females. The age ranged from 68 to 78 years of age. Time since PD diagnosis was between 3.5 and 20 years. All were retired.

Two used smartphones or tablets each day, while the last person did not have a smartphone and used their tablet a few times per week. When asked to assess their smartphone and tablet skills on a scale from 1 to 5 the answers were 1, 2, and 2.5.

One user mentioned that due to motor impairments their little finger often touched the screen involuntary. It made it frustrating to write with a touch keyboard since the user often had to remove text and rewrite. The user had tried using a stylus pen, but it was of poor quality and had to be pressed hard against the screen to register touch. The second user struggled sometimes with touch devices, and the last user had no problems using the touch keyboard on their tablet.

The users were asked if they ever had changed the text size on their devices. None of them had, but two of them were aware that is was possible. Of those two, one user was afraid to go into the settings due to fear of doing something wrong and not be able to fix it, while the other said it was not that important to them.

When asked if they had encountered other problems using touch functions, such as dragging items across the screen, only on said they sometimes “dropped” the card while playing Solitaire. This was not the same person as the one that had trouble writing with the touch keyboard. The other two had no problems.

One user said it was stressful to keep their smartphone with them at all times. Often it was in another room and it would be difficult to always keep track of it. This user had a medicine reminder app that was no longer used since it caused stress.

The last questions before letting them test the prototype was about exercising. One went to a physio three times and to a gym two times per week. The two others had no exercise schedule. One was good at keeping active, but the last user was poor at doing recommended exercising.

They all knew about the importance of exercise to slow down the progression of PD, and that motivated all three to exercise. Avoiding “the last phase in a nursing home” and not wanting to “stiffen up” was also stated as motivational reasons.

5.3.2.1 Feedback on prototype

The users were observed while navigating the app and performing tasks step by step. They were instructed to think aloud, and questions were asked after each step.

For rating exercises, all three users preferred the one with three choices over the 5-star system. See figure 5.7

Figure 5.7 The two different ranking systems tested.

When adding contact persons, it became clear that feedback was lacking in confirming to the user that a new contact had been saved, since the contacts screen only fits four contacts at the same time. When adding a fifth it would appear below the current view and the user had to scroll to find the newly added contact. A solution to this problem was added in the next prototype.

Text entry fields was set to automatically capitalize the first letter. One user did not notice this and tapped the shift-button before starting to write, resulting in the first letter being lower case.

Code had not yet been added to make sure text entry fields was not covered by the keyboard. This was a problem for one user who did not know how to dismiss the keyboard to get to the text entry field behind.

The app "looks fairly okay" according to one user who had nothing negative to say about the prototype. It was difficult for the users to find anything bad when asked at the end of the user test, even after they had encountered issues while using the prototype.

5.3.2.2 Heuristic Evaluation

After seeing users navigate the app it became clear that if and when they needed help, having to go back to the start screen to access the help section would be cumbersome.

5.4 Third Prototype

The help section was removed from the large button on the start screen, and a help button was added to the top right corner of every screen. By doing this, when tapping on help, the user find help related to what they are currently doing and avoids unnecessary steps.

Medication reminders had not previously been added to the prototype and was added as one of the large start screen buttons.

To make sure that the user receives feedback that a new contact has been added a pop-up box to confirm this was considered, but it would demand extra reading and clicking to dismiss the pop-up. Instead, making the screen automatically scroll down to the new contact was chosen to clearly show to the user that the contact had been saved. In the code the scrolling speed was set to clearly let the user see that the screen scrolled down.

Code was added to make sure the keyboard was no longer covering text entry fields. When tapping a text field, it scrolls up over the keyboard.

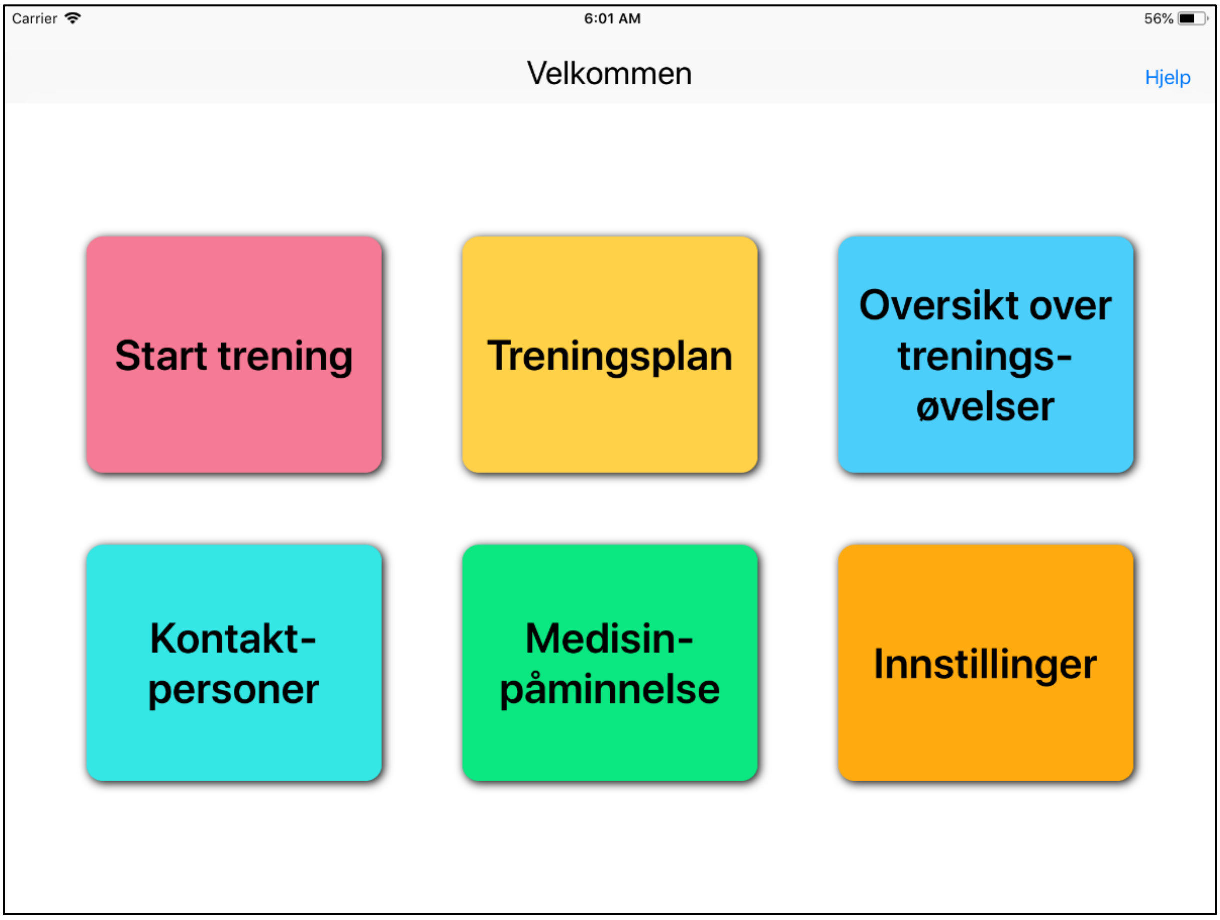

Figure 5.8 The start screen from the third prototype. Top row from left: Start Exercise, Exercise Plan, Overview of Exercises. Bottom row from left: Contact Persons, Medication Reminder, Settings.

5.4.1 Feedback

The physiotherapist previously interview was asked to comment on the prototype. Following is her suggestions for improving the app.

She recommended adding information about why exercise and active measures is important for people with PD. This could be added to the Start Training screen since this will be used most often by users.

The exercises should be based on the user's specific goals and an exercise program should be able to have several exercise plans. Exercise goals should be based on SMART goals (Specific, Measurable, Assignable, Realistic, Time-related). This can be explained in the app to encourage adding SMART goals.

It should also be possible to add programs not directly related to exercising, such as voice exercises for people with PD.

She suggested the user could “cross off” to register completing an exercise and be able to see how many exercise sessions they had completed during the last week.

6 Heuristic Evaluation Based on Universal Design Principles

The goal of universal design is to develop accessible and usable products that can be used by as many as possible, including people with disabilities and the elderly. In this section, the prototype is evaluated based on the universal design principles.

6.1 Equitable Use

The prototype allows the user experience to be customized according to the user's personal accessibility settings in iOS. The exercises, plans, contact persons, and reminders are added by the user, or by someone assisting the user. This makes the app useable by a wide range of users, not only by people with PD.

6.2 Flexibility in Use

By adapting font and button settings according to what the user likes, the app facilitates a wide range of users. If the user struggle to accurately hit buttons, increasing the size will help with hitting the correct target. There are no time limits anywhere in the app, so the user can navigate according to their own tempo. When following an exercise plan, the next exercise can be chosen at any time. If exercise videos with sound and subtitles are added, the user can watch the exercise without having to listen to the instructions. This way the user can have a conversation or listen to music while exercising, and not miss information.

Notifications can be turned on or off according to the users wishes. Medication notifications and exercise notification can have different settings, where one is on while the other is off

6.3 Simple and Intuitive

Many unnecessary elements found during user testing has been removed. Since exercise instructions are added in the app by the users themselves, or someone helping them, the instructions added can accommodate the user's intuition, language skills and other preferences. For some, more detailed exercise instructions including video or images may be necessary to perform the exercises correctly.

6.4 Perceptible Information

When adding exercises, instructions can be added with text, images, video, or a combination of these. By adding videos with voice instructions, it is possible to exercise without seeing the screen. The most important information is given priority when increasing text size.

6.5 Tolerance for Error

The user can go back to the previous screen at any time. When deleting or removing items a warning box pops up with a blue cancel button and a red delete button. If making a mistake when adding an exercise or a contact person, the user can later go back and edit their mistake at any time.

6.6 Low Physical Effort

To minimize touch duration and thus the effort and concentration needed, all inputs in the app is done by tapping items. There is no dragging of items across the screen.

6.7 Size and Space for Approach and Use

Buttons are not close together to avoid the user tapping on the wrong item. Several screens in the prototype lets the user hold the tablet with on hand without covering important information on the screen.

7 Discussion

7.1 Summary

By involving users, both people with PD and health care workers, in every step of the development process, it was ensured that their needs and requirements was taken into consideration. The inclusion of users with physical challenges, also contributes to the end product being more accessible to a wider range of people.

It was important to be able to discuss with health care workers, who are experienced in working with people with PD, when trying to understand and get to know the various aspects of PD related to exercising.

When user testing with people with PD, it is much easier for the researcher to come to the user, than the opposite. It is important that the user feels comfortable during testing and having to travel to an unfamiliar place may cause unwanted stress that can affect the test results.

The data gathered in this study from interviewing users, and discussing their needs and desires for touchscreen interfaces, is relevant not only for design and development of exercise apps, but also for other types of apps involving users with similar impairments.

Based on the user testing of prototypes in this thesis, the guidelines for designing for people with PD provided by Nunes et al. (2016) were valid.

Research have shown that physical exercise in patients with PD is an effective method to control PD-related symptoms, reduce or limit the progress of the disease, and improve physical and psychological health. However, due to PD related conditions exercise adherence is a challenging task. Since adherence to an exercise program often involves a behavioral change, the additional support an exercise app can provide to this process might be a valuable contribution. Adherence to exercise programs is fundamental for achieving positive outcomes. Barriers for continuing regular exercise is decline in health, time constraints, and lack of motivation. An accessible and usable app can help with lowering those barriers.

7.2 Limitations of this Study

The prototypes were only tested with people in the early stages of PD who had experience using touchscreen devices. To make sure the app is accessible and usable by people in all stages of PD, more testing is needed. It should include people with wide-ranging symptoms and diverse smartphone and tablet experience.

How other PD related conditions such as dementia, apathy, excessive daytime sleepiness, and sleeping problems affects exercise adherence and use of mobile devices was not significantly explored.

The cognitive decline that comes with PD was barely touched upon and it is difficult to conclude if the prototype is too complex or how to make it simpler without observing this user group while testing the app.

8 Conclusion and Future Work

8.1 Conclusion

If the app is used as intended, i.e., by adding exercises recommended for people with PD and setting up exercise programs with SMART goals, it can be a valuable tool for helping with exercise adherence.

But a mobile app is not a solution for every person with PD. It is not “one size fits all”. For some, an exercise reminder app can be a great help in adhering to recommended exercise programs, while others may feel mentally overloaded by having exercise notifications popping up on their devices, especially if the also have medication notifications turned on. Therefore, it is important to include options that gives the user a choice in how to use the app.

It is another aid available for people with PD to help slowing down the progression of the disease, but only if they exercise. As the population ages and the younger generations more used to smartphones and tablets become older and affected by neurodegenerative diseases, such as Parkinson’s disease, the desire for using apps like the one described in this thesis will grow. The importance of researching and developing such apps will therefore increase and being on the forefront in this regard may turn out to be lucrative for those who can create accessible and useful solutions.

Another aspect is that if people with PD improves exercise adherence, it will help with relieving the economic and emotional burden on society, health care providers, individual patients and their family.

8.1 Future Work

Further research into finding usable and accessible solutions for people with PD are needed, and this study is barely a start. The prototype must be developed further, and to find out if a mobile app truly can help address the challenges of exercise adherence, a longitudinal study must be conducted comparing other methods.

Many users in this study were positive to using a finished version of the exercise app in the future, but without comparing it to traditional methods an answer regarding exercise adherence would just be guesswork.

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Appendix

Paper accepted to ICCHP 2018

A Mobile App Supporting Exercise Adherence for People with Parkinson's Disease

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Abstract. Researches have shown that physical exercise in patients with Parkinson's disease (PD) is an effective method reduce or limit the progress of the disease and improve physical and psychological health. However, exercise adherence is a challenge task. Many existing mobile exercise apps did not consider the special conditions of people with PD. This paper aims to design a mobile app to support physical exercise adherence among people with PD. Through the design of the app, we hope to test and contribute to the improvement of the existing guidelines and recommendations for mobile apps for people with PD.

Keywords: Parkinson's disease, exercise adherence, mobile app.

1 Introduction

Parkinson's disease (PD) is one of the most widespread neurodegenerative conditions in the world [1]. It is an age-related disease and mostly affects people in the later years of life. As the older population continues to grow, the number of people with PD is expected to increase. Symptoms in PD include tremor in limbs, slowness of movement, stiffness in muscles, and impaired balance [1]. These symptoms result in a loss of fine motor skills. The progressive nature of PD and its increasing prevalence have resulted in a substantial economic burden to society, health care providers, individual patients and their family [2].

Researches have shown that physical exercise in patients with PD is an effective method to control PD-related symptoms, reduce or limit the progress of the disease, and improve physical and psychological health [3, 4]. However, due to PD related conditions such as dementia, apathy, excessive daytime sleepiness, and sleeping problems [5] exercise adherence is a challenging task. Adherence can be understood as the extent to which the patient's behavior corresponds with caregivers' recommendations and follows the mutual agreement to achieve established goals [6]. Since adherence to an exercise program often involves a behavioral change, the addition of support for this process might provide a valuable contribution to adherence. Adherence to exercise programs is fundamental for achieving positive outcomes. Barriers for continuing regular exercise is decline in health, time constraints, and lack of motivation [7]. To our knowledge no previous studies have qualitatively explored the use of digital technology to facilitate exercise adherence after rehabilitation in people with PD.

The usage of smartphones and tablets is increasing among elderly. Various mobile apps have been developed for older adults [8]. Existing exercise apps for elderly people in general, such as Senior Fitness - Strength & Flexibility Training and Daily Senior Fitness Exercise, are not suitable for people with PD, as they do not consider their special conditions. Even the exercise apps for people with PD such as 9zest Parkinson's Therapy and Parkinson Home Exercises have usability issues. For example, some have an interface with buttons too close to each other, which causes mistakes for people with declined motor skills.

To support physical exercises among people with PD, we have designed a mobile exercise app that reminds and motivates people with PD to exercise, following guidelines and recommendations for mobile apps for people with PD and taking their special conditions into consideration. In addition, through the design of the app, we hope to test and contribute to the improvement of the existing guidelines and recommendations.

2 Related Work

The variety of symptoms for people with PD can make this user group difficult to design for and a user-centered design approach is important and efficient when designing solutions for people with PD [9, 10]. As basis for creating their own framework for people with PD, McNaney, Balaam, Holden, Schofield, Jackson, Webster, Galna, Barry, Rochester and Olivier [10] used existing guidelines for participatory design with elderly users. This method was found to inadequately address several specific issues with PD, including speech, general mobility and dexterity, medication, and age difference.

8.2 2.1 Mobile Apps for People with PD

Some mobile apps have been developed for people with PD, for training, self-management, monitoring progression, medication, diagnosis, treatment guides, information (about symptoms and treatment options), analyzing tremor, connecting (with family, experts, and peers), and transportation. Very few have been studied in terms of usability and effect [9, 11]. The Parkinson’s tracker app for Android and iOS is a self-management and adherence tool to manage PD [12]. It was used in a study to investigate whether those who used the app showed improved medication adherence compared to those receiving usual treatment. Participants could review and compare their scores with each other, receive alerts and track medicine intake, they had the option to generate a report detailing the trial period, and play games to track physical responsiveness. The study lasted for 16 weeks and the app was found to have significantly improved adherence, compared to those who received usual treatment. According to the authors, this study had a higher level of user retention because of the design of the user interface and user experience, and simplicity of the app.

8.3 2.2 Guidelines and Recommendations for Mobile Apps for People with PD

Tremor and loss of fine motor skills can cause great difficulty and frustration when using touchscreens for people with PD [10]. The challenges experienced are mostly related to touchscreen gestures [13]. The on-off phenomenon in PD can change the user's ability to interact with a touchscreen or smartphone depending on the situation. Montague, Nicolau and Hanson [14] recommends the use of alternative gesture recognition due to the variance in ability and performance between sessions in individuals with hand tremors.

Chen, Savage, Chourasia, Wiegmann and Sesto [15] studied the effects of button and gap size, and the presence of disability, including PD, on user performance using a touch screen kiosk. When button size increased, there was a decrease in misses, errors, and time to complete tasks. Ten combinations of five different button sizes and two different gap sizes were presented to each participant. Among those with a disability, 84% preferred a button size of 20 mm or larger, and 89% preferred a gap size of 3 mm over 1 mm.

Most recently, Nunes, Silva, Cevada, Barros and Teixeira [11] investigated how PD influences the interaction with smartphones. They researched relevant literature, interviewed healthcare professionals, observed smartphones users with PD, and performed a usability study with 39 people with PD. Four gestures were evaluated: tap, swipe, multiple-tap, and drag. In the end, a list of symptoms that influence smartphone interaction was provided, as well as 12 user interface design guidelines for developing smartphone applications for people with PD.

3 Design and Development

We follow a user-centered approach in the design and development of the mobile app. The initial requirements were gathered based on literature review and focus group interviews with people with PD and health care workers. Based on the requirements we have developed the first prototype.

8.4 3.1 Focus Group Interview

The focus group interviews were conducted in a rehabilitation center with 20 people with PD and 7 health care workers. The most pressing challenge is that after their stay in the rehabilitation center where they have learned how to exercise and live with PD, they have difficulties in following the exercise plan. Ideas for how to support the exercise adherence with the mobile app were discussed. These include showing videos of exercises, allowing care workers to add videos or links to online videos and create/customize exercise plan, reminding users to take medication, which is very important for the effect of physical exercises, and providing contact information to doctor, physiotherapist, or other people who can help with exercises. Some people have also responded that they would like to have the app include functions for self-reporting, so that it can replace the use of paper forms for such purpose. Given the conditions of people with PD, the majority prefer to have the app on a tablet, which has a bigger screen size that a mobile phone.

8.5 3.2 Initial Prototype

Based on the results from the focus group interviews and conversations with experts in rehabilitation for people with PD, we established the initial requirements for the mobile app. They are: remind the user to exercise and take medication; show the user how to perform exercises; support user to create and customize exercise plan; and confirm that exercise has been performed.

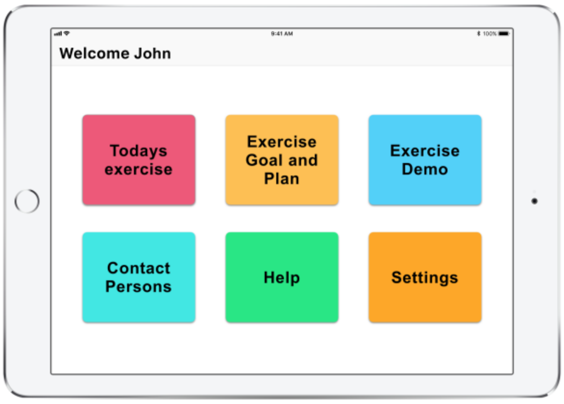

Fig 1. Main interface of the mobile app

Through literature review, we have also selected an initial set of design guidelines and principles to follow during the design of the interface for the exercise app. They are based on the 12 guidelines for designing for people with PD by Nunes, Silva, Cevada, Barros and Teixeira [11] and the 10 usability heuristics by Nielsen [16]. The interface of the prototype is illustrated in Fig. 1 where the users can see today's exercise, a demonstration of exercises, exercise plan, contact persons' information, help information on how to use the app, and how to configure reminders and other types of settings.

4 Conclusion and Future Work

In this paper we aim to address the challenges of exercise adherence among people with PD with developing a mobile app. This app is mainly intended to remind users to exercise and demonstrate to them how-to with videos. We are currently planning for the first user testing with the initial prototype. For the testing, we plan to use leading users who are in the early stage of PD and with reasonable good skills in using mobile phones or tablets. We will combine observation with think aloud protocol. After the observation, an interview will be conducted to collect in-depth information about how the users have experienced the app. The feedback from the user testing will be used to further develop the app.

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