Literature study of eHealth solutions for treatment of Parkinson's disease

SSY115 - Health Informatics

Group 3

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Abstract

Parkinson's disease (PD) is the second most common disorder affecting the nervous system. Worldwide, up to 10 million people are estimated to be diagnosed with PD [1] and the disease can therefore be considered a global health issue. Today there is no cure to stop the progression of the disease. It is therefore motivated to continue the study of PD and develop several solutions aiding people diagnosed with he disease. The most prominent symptom of PD is the degeneration of motor functions but there are also non-motor related effects. Since every person experiences different symptoms, it is necessary to provide a diverse set of treatments. The increased usage of smart devices provides a possibility of developing digital patient-based solutions aimed to be used at home. This literature study presents various e-Health solutions for an efficient monitoring of different symptoms experienced by persons diagnosed with Parkinson's disease. Solutions are presented for each of the four motor related symptoms described by the TRAP acronym (Tremors, Rigidity, Akinesia - slowness of movement, Posture). Further, an additional solution related to m-health platform is discussed. A comparative study of these solutions are presented, resulting in the conclusion that many solutions are aimed for motor related symptoms but there is a lack of methods providing treatment for non-motor related symptoms. Lastly, it is predicted that an increase in affordability and user-friendliness of smart devices will lead to an increase of such eHealth solutions for Parkinson's disease.

Keywords: Parkinson's disease, TRAP, eHealth, neurodegenerative disorder

Contents

List of Abbreviations

AR Artifical Reality

DBS Deep Brain Stimulation

EMG ElectroMyoGraphy

FOG Freezing of Gait - a possible motor symptom of PD.

PD Parkinson's disease.

PDP Person(s) diagnosed with Parkinson's disease.

TRAP Tremor - Rigidity - Akinesia - Posture. Categories of motor symptoms in Parkinson's disease.

m-Health mobile Health

1 Introduction

The following section provides a theoretical background describing Parkinson's disease. This information is necessary to follow the later presented and discussed digital solutions aimed to aid people diagnosed with the disease. Finally, the aims and limitations of the study are declared.

1.1 Background

Parkinson's disease (PD) is estimated to be the second most common disorder affecting the nervous system (i.e. the nerves and the brain) [1]. Around 3% of the population in Europe has been diagnosed with the disease and $60,000$ new cases are detected each year in the U.S.. As of today, around 7-10 million people worldwide are diagnosed with PD and this number is expected to increase dramatically over the coming two decades, as the global life expectancy is getting higher [1]. Currently, there is no treatment available to reverse the progression of PD but measures can be taken to ease the severity of the symptoms as experienced by the patients.

As mentioned above, PD is a disease which affects the nervous system. This system is responsible for assisting with both voluntary and involuntary movements of the whole body. The neurons (nerve cells) acting as messengers in a human body produces a chemical substance called dopamine. For a person with PD, a transition occurs such that the neurons either die or get impaired which leads to a decrease in the dopamine production. As a result, a person with previously normal movement begins to experience mild symptoms of irregular movements, imbalance and slurry speech. As the reduction factor of dopamine keeps increasing over time, the severity of the symptoms also increases. This results in a loss of nerve endings which at a later stage leads to abnormal motor skills, as well as a possibility of an increased stress level and irregular blood pressure. The loss of neurons is one of the main contributing factors to the onset of Parkinson's disease and scientist are underway to find the root cause for this process. [2]

The early-onset of Parkinson's disease is usually identified from symptoms like shaking (tremor), stiffness (mostly prevalent in the dominant hand) or slowness of movement. The symptoms gradually worsens over time leading to difficulty with balance and the coordination of motor skills. At an early stage, the patient's face may show very little to no expression, the involuntary arm swing while walking might not be visible and changes in speech tone and texture can occur. As the disease progresses, a patient may have difficulty to integrate with all the skills required for a normal routine to live a healthy life. To get a better view of the onset of disease along with its symptoms detected at various stages and the severity level, the figure 1holds good. Despite the fact that the cause of PD is unknown, some factors such as age and stress, family history along with environmental toxins (with particular focus to pesticides, drug abuses and toxins) are deemed to be responsible to promote the disease. PD is known to affect irrespective of gender. However, the disease affects about 50% more men than women.[2]

There are several symptoms related to PD. The most prominent symptoms are motor related but there are also cognitive and behavioural changes as well as autonomic system failures. Common non-motor symptoms experienced by persons diagnosed with PD are sensory, sleep and mood disturbances. The motor related symptoms are often described by the TRAP acronym, where T stands for tremors, R for rigidity (stiffness), A for akinesia (slowness of movement) and P for postural instability. These are often what first leads a person to seek care for PD. Since different people experience different symptoms, the treatment has to be highly individualized. There are several measures to be taken in order to ease the severity of the symptoms. Both pharmacological and non-pharmacological approaches, such as exercise, education, nutrition and support group speech therapy, can be taken. In rare and very specific cases, it is also possible to take surgical therapies into consideration. These include deep brain stimulation (DBS) leading to a decrease of the ability of dopaminergic neurons to absorb dopamine.[2]

Since the complication of the disease is high, multidisciplinary management of the disease involving several professionals (neurologist, psychologists, physiotherapists, speech and language therapists, occupational therapists, dietitians etc.) are recommended for the self being of the patient. It is highly inconvenient for a patient to visit a hospital on a daily basis (especially during the last year with the COVID-19 pandemic) for a consultation with a doctor. Hence, the usage of various eHealth solutions could play a major role here. Using such digital solutions, it is possible for the involved doctors to monitor and assess the severity of some symptoms for persons with Parkinson's disease without the need of an in-person meeting. Upon diagnosis, it makes it less stressful for the doctors to offer dedicated nutrition, physiotherapy and certain educational videos. Few eHealth solutions embed with the latest technologies available on market while few have inbuilt applications like medication reminders, latest articles and research trends, discussion forums and attractive games like finger tapping, ball bouncing,etc.., that helps patients to aid with their memory loss and assist with daily living.[3]

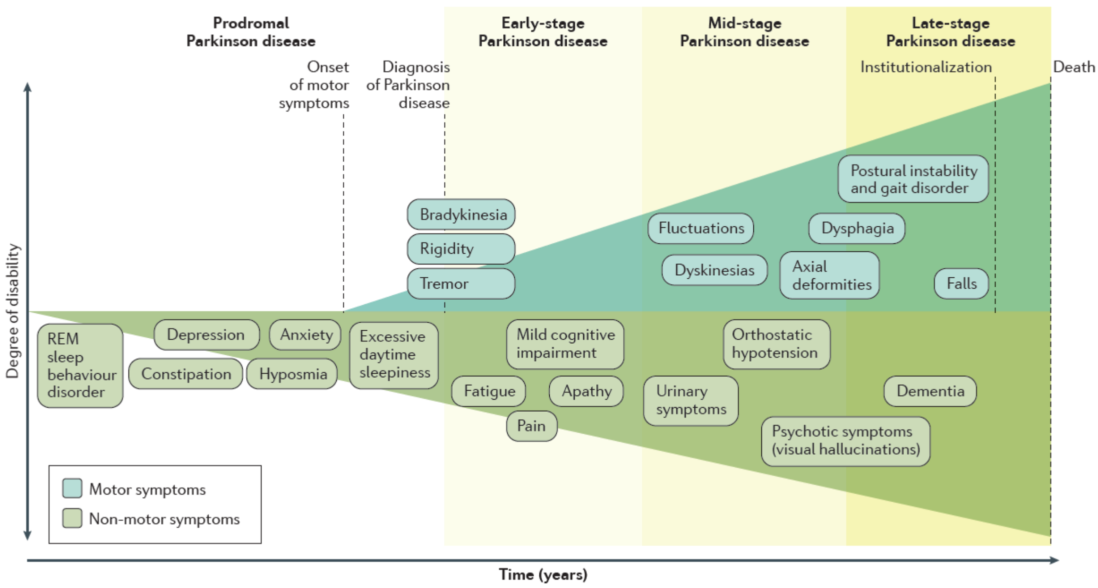


Figure 1: *Motor and Non Motor symptoms related to Parkinson Disease [4]*

1.2 Aims

The overall aim of this literature study is to provide a brief description of Parkinson's disease as well as several eHealth solutions aimed to facilitate the everyday life for people diagnosed with the disease. Below follows a list specifying the aims of the work.

1. Provide a brief description of Parkinson's disease in terms of
    1.1. biological difference between a healthy person and a person with the disease
    1.2. possible symptoms
    1.3. possible treatments available today
2. Identify possible eHealth solutions related to treatment of Parkinson's disease based on the findings in aim 1.
3. Identify pros and cons with the solutions in aim 2.
4. Make a comparative analysis of the solutions in aim 2 based on the findings in aim 3.
5. Identify what is missing regarding eHealth solutions based on all above aims.

1.3 Limitations

Parkinson's disease is a well studied phenomena but there is a lot that is not yet understood. Thus, there is much information available on the subject and some limitations for this project has therefore been formulated. First of all, only a brief description of the disease and its consequences is presented since there are many reviews and sources including this information already available[1]. Further, only solutions for people with mid-stage PD has been considered. This is partly to enable a sufficient analysis, partly since many state-of-the-art digital solutions focus on this phase of the disease. Here, mid-stage PD is stage 3 PD as defined by The Hoehn and Yahr scale [8]. Thus, this study is focused on patients possibly experiencing tremors, slowness of movement and imbalance as well as speech impairment and difficulties in facial expressions. Finally, the presented solutions are aimed to display a variety in treatment methods both regarding covered symptoms and technical approach.

2 Methods

In order to fulfill the aims presented in section 1.2 a literature study was performed. Initially, a general search through various scientific databases, namely PubMed, IEEE, Science Direct, Google Scholar and Chalmers University of Technology Library, was made. In this phase, the used search terms were some combination of *'Parkinson disease'* and at least one of the following keywords: *'treatment'*, *'digital solution'*, *'review'*, *'e-Health'*, *'m-Health'* and/or *'embedded systems'*. This resulted in a large amount of articles, which were critically analyzed to enable a careful selection of studies to investigate further. The selected texts provided an introductory understanding of the disease and the current state-of-the-art regarding innovative solutions in this area.

To further fulfill aim 1-5 from section 1.2 the knowledge gained from the above procedure was used to make a more specific search through the previously mentioned databases.

[1] see eg. [5], [6] and [7].

In this phase, keywords such as *'Quantification of rigidity in PD'*, *'Treatment of tremors AND PD'*, *'TRAP treatment'* and *'Sensors for measuring akinesia OR tremors'* were used. Since e-Health has been a fast developing technology during the last decade [9], only more recent (after 2015) studies were included in the selection of potentially interesting articles. Following the limitation regarding only presenting solutions for mid-stage PD, as presented in section 1.3, studies describing methods and technologies for an early-detection and/or diagnosis of PD were excluded. Moreover, to get a broader understanding of the topic and the currently available mHealth solutions, several mobile applications have been downloaded and briefly tested. The tested apps were "CYPD", "Parkinson's disease manager", "Parkinson's Rehab", "PD warrior", "Peak" and "FonateDAF - Stuttering help". These were all aimed to aid in the physiotherapy and help a person diagnosed with PD to cope with the disease.

3 Results

The following section presents four patient-directed eHealth solutions for a facilitated tracking and monitoring of the symptoms experienced by persons diagnosed with Parkinson's disease (PDP). As previously mentioned in section 1, a common symptom of PD is some sort of motor impairment. However, there are also symptoms which are not related to motor functions, such as sleep deprivation, speech impediments and hyposmia (i.e. the impairment of the sense of smell) [10]. Thus, various solutions covering different types of symptoms might be needed to fully monitor the progress of the disease. This motivates the selection of the eHealth solutions presented in section 3.1-3.5. Initially, eHealth solutions based on the TRAP mnemonic (i.e. covering motor impairment) are presented, followed by a description of a mHealth solution aimed to monitor both motor and non-motor related symptoms. The symptoms which each solution covers is also summarized in table 1 below.

Table 1: Summary of which symptoms are covered by which solution.

	Symptom
Solution 1	Tremor & Akinesia (slowness of movement) - T & A
Solution 2	Rigidity - R
Solution 3	Postural instability (imbalance) - P Inability to balance
Solution 4	Freezing of Gait (FOG)
Solution 5	m-health platform

3.1 Solution 1: A wrist-worn wearable device for tracking resting tremor and slowness of movement

A person cannot be diagnosed with PD without experiencing an increased slowness of movement. Further, one of the most common symptoms experienced by persons seeking care for PD is hand tremors [11]. Thus, tracking both tremors (the T in TRAP) and such movements (the A in TRAP) is significant for monitoring the progress of the disease for many persons with PD. A common solution for tracking some sort of movement is the use of sensors. In particular, accelerometers and gyroscopes are commonly used in devices related to PD. An accelerometer can only be used to monitor a change of speed, while a gyroscope can be used to detect a change of both speed and direction [12]. However, while the latter is more accurate it is also more computationally expensive and a wearable device comprising this does therefore require a larger battery [10].

One example of a digital solution for the tracking of resting tremors and slowness of movement is presented in a recent study (published 2020), describing a wrist-worn wearable device aimed for individual at-home usage [10]. An illustration of such a setup is presented in figure 2. The device is a body area network (BAN) based on an accelerometer and machine learning (ML) techniques aimed to identify the presence of tremors and/or slowness of movement in a patient diagnosed with PD. To enable such an identification, data was collected from 60 healthy persons (HP) and 35 persons diagnosed PD. This was achieved by letting the device identify the presence of the relevant symptoms. These measurements were later compared to a clinical rating performed by experienced examiners. The comparison demonstrated a sufficient compliance between the two methods. On the contrary, a distinction was observed between the severity of the symptoms reported by the device and the severity reported in the form of a self-evaluation by the trial persons. It was therefore concluded in the study that the device could perform equally well as a clinical evaluation and prevent the presence of a bias as introduced during a self-evaluation process.

Figure 2: *Example of a wrist-worn wearable single sensor device aimed for at-home usage. [13]*

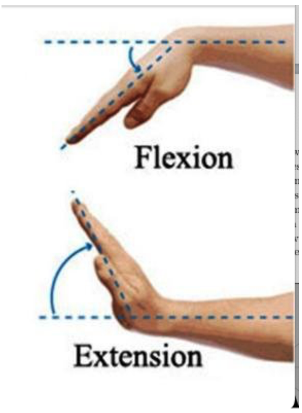
In addition to the analysis of the performance in detecting the relevant symptoms, the ease of use of the device was analyzed. It was concluded that a single sensor was preferred over multiple ones and that a slight decrease in sensitivity was preferred over a larger battery (which as previously mentioned would be a result of a more power consuming device). Based on this and a rating performed by the trial persons regarding the user-friendliness, the overall ease of use was inn the study concluded to be sufficient [10].

3.2 Solution 2: Quantitative measurement of rigidity in Parkinson's disease.

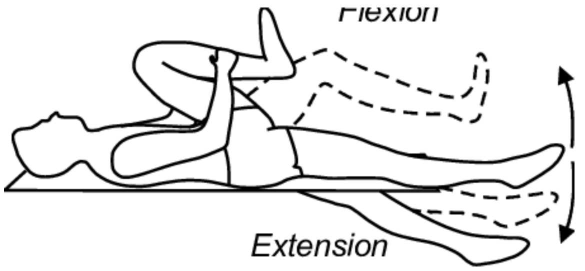
Out of the four cardinal motor symptoms (TRAP), it is estimated that upto 89% of patients diagnosed with Parkinson's Disease are prone to experience rigidity [14]. In medical terms rigidity can be referred to as muscle stiffness or resistance to passive movement typically assessed and compared against clinical scales.

Several teams of biomedical engineers and researchers belonging to neurology units came up with different ideas to measure this rigidity factor quantitatively so as to enable self-assessment at home in a convenient manner. Throughout the case studies, rigidity was assessed using sensors, motors and biomechanical and neurophysiological study of muscles. According to sources used in all the case studies included in this solution it showed good reliability, good correlation with clinical scales and were useful for studying its evolution.

Table 2 showcases a comparative study of the quantitative measurement of rigidity factor that was assessed between Parkinson's Disease (PD) patients and healthy subjects. The table provides an overview of on what physical conditions the trials were conducted with the end results obtained. Further, an illustration of each of the presented devices are given in figure 4 to give an idea of it's physical features worn during the flexion-extension movement during assessment as illustrated in figure 3.



(a) *Arm flexion-extension [15]*



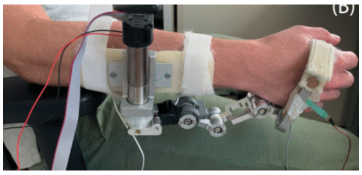
(b) *Hip-Knee flexion-extension* [16]

Figure 3: *Flexion-extension of upper and lower limb region*

In table 2 the following statements holds good.
** - 1 Cycle here refers to a flexion along with an extension.*
*** - Quantitative measure of wrist stiffness factor.*

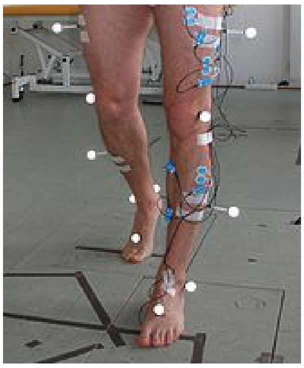
Table 2: *Overview of case studies for quantitative measurement of rigidity*

Used to Measure	Type of Movement	Number assessed for clinical trials	Condition examined	Results
Case study 1 : PDMeter [17]				
Wrist stiffness	Arm flexion-extension with 5 repeated cycles*	7 PD, 14 healthy	Device fitted to right arm in relaxed state, • PD subjected examined twice with 1. PDoff - PD subjects on medication at highest efficacy. 2. PDon - PD subject on no medication.	$(\mathrm{K}_E, K_F)^{**}_{PDon} >> (K_E, K_F)_{PDoff} >> (K_E, K_F)_H$
Case study 2: NeuroFlexor [18]				
Wrist stiffness	Arm flexion-extension with 5 slow stretches followed by 10 fast stretches	25 PD, 14 healthy	Device fitted to forearm and tested under following 2 conditions. • Dynamic - user at relaxed state. • Passive - device on one hand, while a movement given on the other hand.	End results coherent with the clinical scale.
Case study 3: Surface EMG [14]				
Lower limb rigidity (hip, knee & ankle)	Hip-thigh flexion-extension with 3 repeated movements	8 PD, 16 healthy	Sensors placed on hip, knee and thigh regions	Muscle stiffness at the hip, knee and ankle regions was at least with a mean measure of 1.5 times higher in PD patients than healthy persons.
Case study 4: BiRD [19]				
Finger stiffness	Finger flexion-extension with 15 continuous cycles.	25 PD, 22 healthy	Device placed at the base of the third finger. • Users asked to draw an imaginary circle in air with most affected as well as less affected hand with DBS device [20] in ON and OFF state but PD subjects stopped medication the night before.	Stiffness in Parkinson's patients gradually increased after the DBS device was turned off within an hour while stiffness was eased immediately when DBS was switched back to ON state.

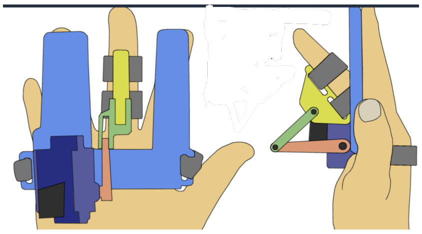


(a) *PDMeter [17]*

(b) *NeuroFlexor [18]*



(c) *Surface EMG electrodes at lower limb [14]*



(d) *BiRD [19]*

Figure 4: *Devices used to measure rigidity. Figure (a) belongs to case study 1, (b) to case study 2, (c) to case study 3 and (d) to case study 4.*

3.3 Solution 3: Postural Instability in Parkinson's disease

Postural instability (i.e. balancing issues) is one of the primary motor symptoms of PD. Postural instability is the instability of the patient to stand. A patient experiencing postural instability may easily fall backwards, which may lead to fracture. In olden days, postural instability was considered as a feature of last stage Parkinson's disease. But now it is one of the prominent symptom for postural instability and gait difficulty (PIGD), one of the subtypes of Parkinson's.

Postural instability is seen in PD patient while standing upright, rising from a bed or a chair. Their inability to balance often causes injuries and fractures. Postural instability is one of the most stressing symptom of Parkinson's, that greatly diminishes individual's level of mobility. There are many clinical tests, assessment scales, bio and biomechanical markers, and gait predictability techniques available to diagnose and scale, the level of postural instability. The prominent among these is the pull test, which is used to assess the postural instability [21].

The pull test is used to assess the potential of the patient to recover from a backward pull on the shoulders. The major task in pull test is the evaluation of imposed backward pull. To support this pull test a wearable inertial modulus **??** is placed on the patient's chest. This inertial unit has accelerometer and gyroscopes, which measures the strength of the backward pull. Using that measurement, Postural instability is assessed [22]. Instruments like force plates 5a are used to measure the pressure on the feet, which assists in standing [21].

Wearable airbag jacket and vest has been designed by a Chinese company to prevent

(a) *Force plate [21]*

(b) *Wearable inertial modulus [22]*

elderly from fall. The system detects the difference between normal posture and improper posture and avoids the potential risk of fall or any injuries to head and hip region. The airbag is designed to act at a rapid way such that it is released within 0.18 of a second [23].

3.4 Solution 4: Wearable glasses aimed to reduce the occurrence of freezing of gait

In addition to the motor symptoms described by the TRAP acronym there is also so called freezing of gait (FOG). This is defined as the absence or reduction of the feets' forward progression, despite the intention to walk. This sort of motor symptom can reach a daily occurrence and is particularly prominent e.g. when initiating a gate, turning around a corner or standing up after having been seated. It has been shown that the FOG experienced by a PD patient can be considerably reduced by using some sort visual or auditory cue. For instance, in 2017 Ahn et al. [24] developed a smart AR-based visual guidance system in the form of wearable glasses, as showed in the 6. The glasses are used to monitor the patient's walk to further enable a detection FOG. If a FOG is detected, a visual pattern is projected on the glasses, 7. The pattern is in the form of straight lines orthogonal to the direction of movement, experienced to be placed on the ground. This is to fool the eyes that the gait is continued instead of interrupted. The study of the developed system showed a remarkable improvement in the mobility and fastening the walk pace of the patient. Results showed that persons that wore the smart glasses showed an increase in walking velocity of 32.1% and stride length of 24.0% compared to the case without glasses.

3.5 Solution 5 : PD_Manager - a mHealth platform

People affected by PD might experience also non-motor symptoms such as psychiatric and cognitive alterations as well as neuro-vegetative symptoms, namely a progressive degeneration and loss of sensory and cognitive function[25]. Thus, in the last year new holistic approaches has been studied in order to have a holistic and complete view of the disease.

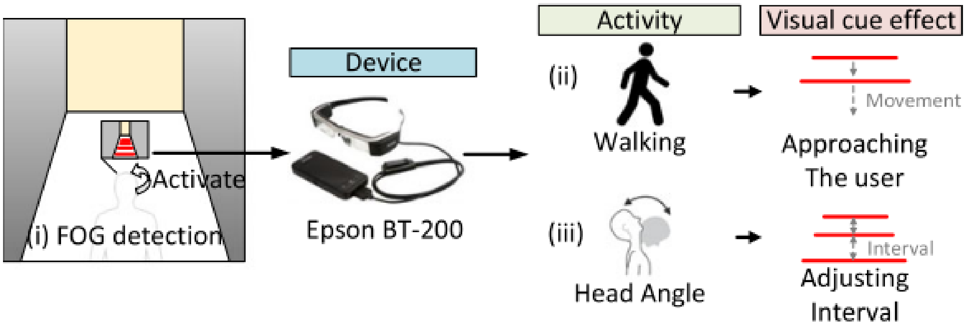


Figure 6: *Smart gait-aid system based on FOG detection and movement recognition [24]*

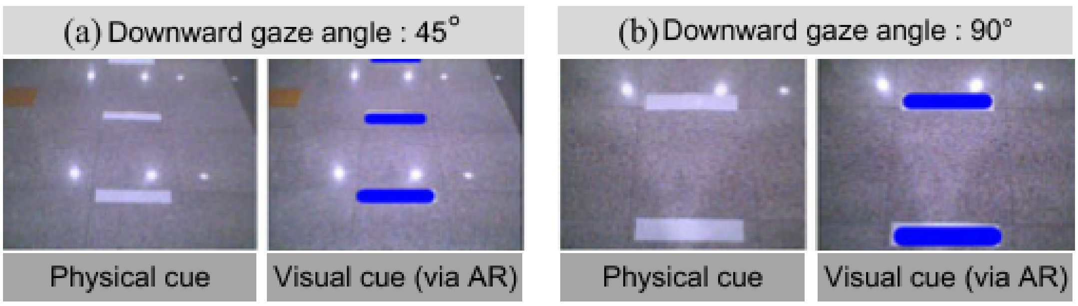


Figure 7: *Comparison of real physical cues and virtual cues projected by the system [24]*

In 2015, a project called PD_Manager, based on mHealth was founded with the aim to create a multidisciplinary disease management. This was to involve the participation of several different professionals such as neurologists, physiotherapists, speech and language therapists, occupational therapists and dietitians, in order to have an holistic and joint approach toward the disease that contemplate the management of both motor and non-motor symptoms [26]. Moreover, the main idea was to enable a patient-centered approach and have a cooperation between the clinicians in order to assure a better quality of life for the patient 8 [27].

The platform was created to be easy-to-use, based on mobile devices with the chance of integrating wearable devices such as insoles and wristband. The wearable device acquires data such as measurement for distribution of pressure, acceleration, weight-bearing, balance, motion sequences, continuous heart rate, motion, skin temperature, and daily activity. The non-motor symptoms, such as anxiety, emotional stare, cognitive status, speech disturbances and sleep disorder is updated on the app by the patient itself [27]. Continuous reports of the patient's current status is further sent by the platform to the clinicians to suggest possible changes of treatment, medication plan or management of new symptoms. Additionally, the platform is able to specify the patient adherence to the treatment, reporting to the clinician and motivating the patient to comply to the program. On the other side, the patient will receive recommendations, change of the medication plan, diet, activity and physiotherapy through the app. Moreover, the platform is able to inform the caregivers of alerts in case of danger of the patient, namely in case of falls [26].

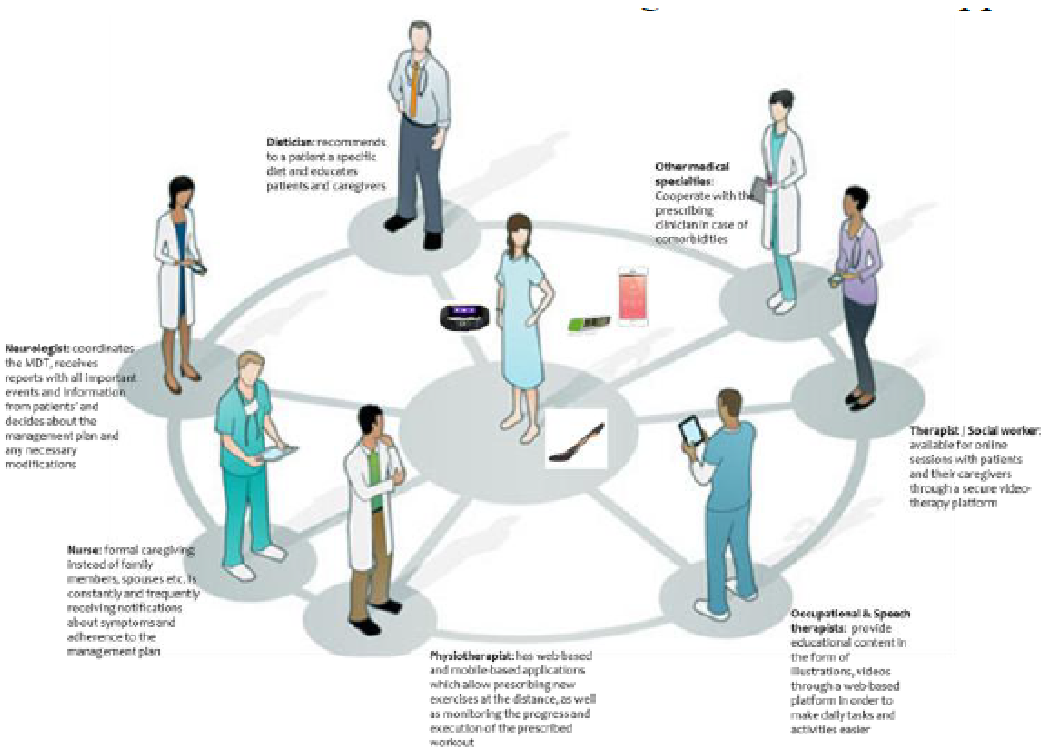


Figure 8: *The patient centered paradigma presented by PD_Manager [27]*

4 Discussion

This section will provide a thorough discussion of the digital solutions presented in section 3 in terms of covered symptoms and usability.

4.1 Analysis of solution 1

The overall usability of the digital device presented in section 3.1 was in the study concluded to be sufficient. This was mostly based on the simplicity of the sensor (as experienced by the trial persons) as well as its placement on the body. In the study it was reported that the users preferred to use a single sensor rather than several ones and that a lighter device with the consequence of a loss of accuracy, was preferred over the opposite. However, it can be argued that these results are not sufficient to conclude an overall adequate user-friendliness. It is to be expected that fewer, smaller and lighter sensors are preferred in devices aimed for everyday use. It is therefore necessary to compare the device to similar ones already in use, to conclude if it de facto is user-friendly. As an example, to determine whether to use an accelerometer or a gyroscope, the trial persons were asked if a smaller battery (as in an accelerometer) was preferred over a better accuracy (as in a gyroscope). However, it was nowhere mentioned that most smart watches already have a built-in gyroscope. A more accurate question could therefore have been if the trial persons would prefer a separate device which could only be used for the specific tracking (i.e. an accelerometer), or an embedded function in a smart watch (i.e. a gyroscope). To answer this, the question of affordability has to be discussed. Using a separate device solely aimed for tracking of symptoms related to PD would probably be less expensive than using a smart watch. However, if the patient already uses a smart watch, it would not be necessary to use an additional device and the probability of the patient actually wanting to use it would probably be greater.

4.2 Analysis of solution 2

The end results obtained with all the devices for measurement of rigidity factor were coherent with the clinical scale.

While devices like PDMeter and NeuroFlexor proved that they could serve as a useful biomarker for rigidity but always need to be assessed in a manual environment. Findings from NeuroFlexor could not be validated due to the lack of EMG measurements, but proved that 'neural component' as one of the contribution factor to rigidity. Future study of PDMeter includes higher sample of PD patients and assessment in unstructured environments while research work is underway for BiRD to enable self-assessment at home similar to a blood-glucose monitor for diabetics for it's relatively small size and easy handling but case studies related to this are yet to be validated.

As the famous saying goes "An ounce of prevention is worth a pound of cure.", it also binds well as one of the aiding factor to slow down the progression of rigidity in Parkinson's disease. The European Parkinson's Disease Association (EPDA) has identified specific prevention and treatment during which could serve as a betterment factor for rigidity and slow the progression of the disease by maintaining flexibility, positive attitude and mobility [28]. A few of them are listed below.

- Consultation with Phyisotherapy, speech therapy and occupational therapy.
- Inclusion of simple exercises and activities that tire muscles in daily routine along with prescribed medication.
- Maintain a calm and peaceful environment.
- Rearrangement of furnitures and fasten loose rugs securely to avoid fall and access to free movement.

For more information about the list of videos related to coping strategies where users share their own experience on how specific exercise/activity helped them to cope up with their daily living, please refer [28]

Figure 9: *Examples of activities to reduce rigidity*

4.3 Analysis of solution 3

Postural instability is the incurable symptom among PD resulting in morbidity. But, it can be controlled by practising therapies and exercises, namely balance exercises improves postural instability and gait difficulty. Physical and occupational therapies helps the patient reduce the risk of injuries and falls. For some patients with severe postural instability, wheelchair use is recommended for transportation[29].

4.4 Analysis of solution 4

The solution presented in section 3.4 has the potential to empower people with PD by providing everyday assistance in self-management of their symptoms. The study presented the development for the very first time of a real time detector of FOG episodes implemented on smart glasses. As mention by the authors it is a very promising finding in the approach to the management of the gait symptoms. In fact, previous studies developed a similar system based on accelerometers located in 5 position of the lower part of the body, meaning an easier detection but a less user friendly solution. By positioning the sensors on the glasses, researchers found that the algorithm still has a 92.86% accuracy, even though less amount of sensors are used and movement is analysed only through the step length.

The potential of the device is remarkable, particularly more functions may be implemented and added to the current one on the glass, leading in the future to a considerable improvement of quality life in PD patient. On the other hand, some issues need to considered. In fact, people suffering from PD, due to their age, tends to reject the technology and be doubtful about the effectiveness of the solution. Another issue that must be mentioned is the fear of fleeting attention related to the use of glasses. Further, in the last years some concerns have arisen towards the safety, the privacy and the violation of intellectual properties in the use of smart glasses, that might have threatened further development along this track [2]. Nevertheless, it still remains a very interesting finding in the field that ought to be important mentioning.

4.5 Analysis of solution 5

The innovative approach used in the section 3.5 has a remarkable potential. The revolution consists of a patient-centered and a multidisciplinary approach with the goal to join the current treatment towards Parkinson. Thus, the following solution proposes a possible monitoring and assessment of PD condition in everyday life. This particular solution underline for the first time the importance of an holistic overview and approach toward the disease, giving a considerable importance to non-motor symptoms. Even though there are the less evident, these kind of symptoms are the one that affect mostly the quality of life. On the other hand, during the research for the report unfortunately only this platform has been found concerning mHealth and not a lot of studies has been found around the testing of the app. In the future, the hope is to have more evidence and proof of the effectiveness of the platform.

4.6 Comparison of the presented solutions

Below follows a comparison among the various solutions, in order to stress the main feature and the further improvement that can be taken in the future.

As far it concerns solution 1, 2, 3 and 4, wearable and accessory devices are needed. Solution 1 can be implemented in a smart watch, very spread nowadays and also affordable device, although it is reduced to limited functionalities. Unfortunately, the same issue is applied to solution 2 along with the user-friendliness resulting in hesitation of people towards the advance technology. On the contrary, even though solution 3 is an accessory as the previous one, users have found it very lightweight and comfortable leading to a more confident way of walking and feel of safety, important since it leads to an improvement of patient's quality of life. Moreover, it must also be mentioned about the product durability,while the device needs to be charged wirelessly for 6 hours,it can be worn for a week.

However, the user-friendliness and patient-center solutions are features that researches should pay more attention to in the future to develop promising solutions for PD treatment and management as well as the aim to concentrate the monitoring of the symptoms in less sensor and devices ad possible in order to make it easy-to-use and easy-to-wear. Despite this factor, the solution presented remains very promising and innovative. In particular, the solutions can be the start-idea for further project and developments.

On the other hand, other issues concern the solution 5. In fact, solution 5 seems to be designed to be user-friendly and patient-centered. This is a very good indicator of the possible future spread of the platform and use among patients. As a result, there is the possibility to build an universal library and data collection among the patient leading to an improvement compared to the ordinary and current methods such as personal diaries as well as the chance for the clinicians to have a good understanding of the disease itself, the progression of the disease and the patient conditions. Even though it seems to be a good solution, the main concern remains the personal data treatment and the use. Specifically,

[2] see e.g. [30]

studies and work need to be conducted in order to assure always a fair use of personal data and having a clear consent from the patient for the use of them.

4.7 Further developments

Even though the progress and development of the technology is extraordinary fast and over the years there are more and more chances to integrate the current eHealth innovations, currently most of them are not adopted. There are several reason behind these obstacles. Firstly, the users are not confident with the use of tech-devices along with the deployment of one or more devices or platforms that make the solution user-friendly. Moreover, one of the main barriers largely reported among the studies read is the consistence and the adherence of the patient to the treatment leading to a failure or to a non-sufficient evidence to sufficiently validate the study. In addition, the more sophisticated and innovative the device, the more expensive it is. This aspect, even though is not considered during the study and development phase, is fundamental since it might foresee the usage and the spread among the patients. Furthermore, patient are not willing to spend money even though the benefit is high due to the cost of the devices.

A recent statistical survey [31] helped to find the factors that showed non-adherence to therapy session for PD.

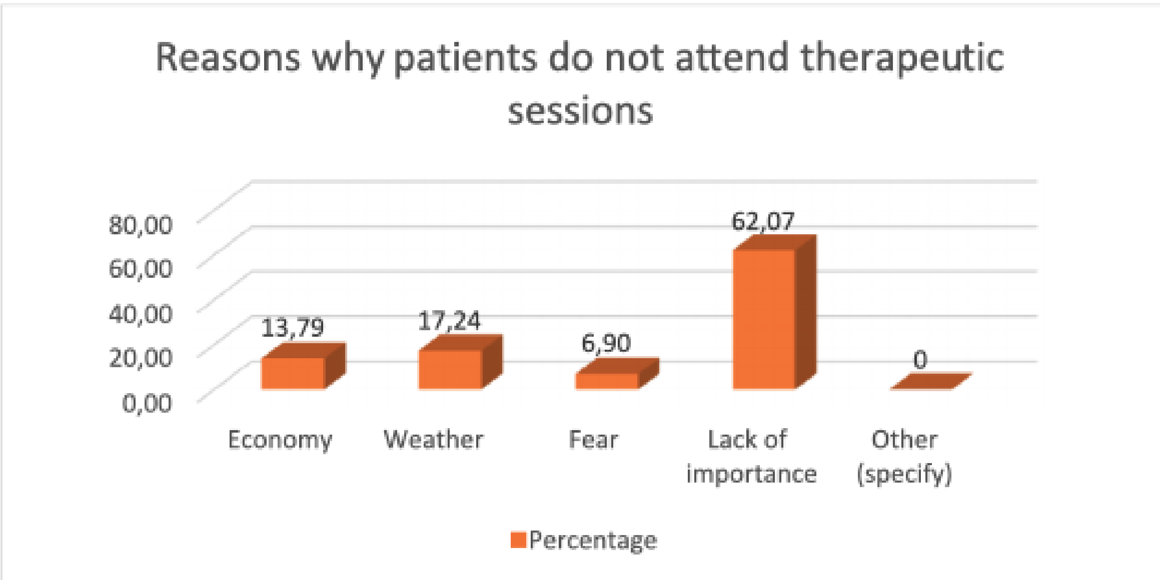


Figure 10: *statistical survey of non-adherence to therapy in PD*

This clearly shows that awareness to detect PD at an early onset is as important to attend the advised therapy sessions to slow down the progression of the disease.

Moreover, the physiological effects must not be neglected since the impact in the patient quality of life is extremely huge. Needing to wear huge, noticeable or uncomfortable device lead to the rejection of the same even if there some benefit.

5 Conclusion

One of the main aims of this work was to give the reader an understanding of Parkinson's disease. This was mainly done using a comparative study of various e-Health solutions focused on different symptoms. It was found that the most digital solutions available today focus on some of the motor symptoms in the acronym TRAP. It was observed that in many solutions, at least one wearable device was needed for tracking one symptom. It was therefore concluded that such solutions are not very likely to be used in combination, since it would result in a person having to wear too many devices on a daily basis. In addition to these solutions, a m-Health solution aimed to track both motor and non-motor related symptoms (such as sleep and anxiety) was presented. It was concluded that such a broad solution was rare, which further was supported by the fact that the previous solutions only were aimed to cover one or two symptoms each. Further, it was concluded that there is a lot of future potential in regards to eHealth for PD.

A Division of work

During the process, the whole team has had weekly meetings discussing the work in general. Thus, all team members have been involved in the decisions of which digital solutions to present and what to include in the report. Further, Chiara has made a lot of research about the disease itself and provided most of the information found in the introduction, Kanniga has researched a lot of digital solutions and Johanna has had a main responsibility of maintaining a consistency of the report. Collaboration between the team members was overwhelming by always maintaining a positive feedback loop. The writing was divided between the group members as presented in the list below.

Abstract: Johanna

1. Introduction
   - **1.1.** Background: Chiara, Johanna, Kanniga, Shivani
   - **1.2.** Aims: Johanna
   - **1.3.** Limitations: Johanna

2. Method: Chiara

3. Results
   - **3.1.** Solution 1: Johanna
   - **3.2.** Solution 2: Kanniga
   - **3.3.** Solution 3: Kanniga, Shivani
   - **3.4.** Solution 4: Chiara
   - **3.5.** Solution 5: Chiara

4. Discussion
   - **4.1.** Solution 1: Johanna
   - **4.2.** Solution 2: Kanniga
   - **4.3.** Solution 3: Shivani
   - **4.4.** Solution 4: Chiara
   - **4.5.** Solution 5: Chiara
   - **4.6.** Overall comparison: Chiara

5. Conclusion: Johanna

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