DESIGNING ENGAGING PREDIAGNOSTIC GAMES

USING DESIGN THINKING AND THE GAME MATRIX TO INCREASE ENGAGEMENT OF OLDER ADULTS WITH PREDIAGNOSTIC GAMES

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Abstract

In this thesis we apply Design Thinking (DT) to a real-world problem: the detction of Parkinson's Disease (PD). PD is a neurological disorder and ranks as the second most common neurodegenerative disorder worldwide. Timely detection can positively influence the type and dosage of medication prescribed, ultimately enhancing patients' quality of life. Typically, patients visit the clinic during their downtime, guided by their perception of symptom severity. Often, patients misinterpret the clinical evaluation process. Since early 2020, the number of clinical visits has decreased, particularly among older adults, who face a higher risk of COVID-19 infection. Consequently, implementing remote monitoring and symptom tracking for PD could improve daily living for patients while conserving valuable healthcare resources. Numerous research studies exist focusing on PD prediction and severity assessment through data-driven methods alongside many mobile applications designed for tracking PD symptoms remotely. However, most research tends to focus on a singular symptom, even though PD is complex and multifaceted. Additionally, the participant pools for these studies are often limited, and many mobile apps face challenges with user engagement and commitment. To tackle the challenges associated with data collection, we propose utilizing mobile games as a viable solution. To create those games, we adjusted the

DT methodology by replacing the ideation phase with the Game Matrix (an alternative to Morphological charts) for a human-centered design. In addition to evaluating the resulting games, we evaluated the experiences of first-year students with Design Thinking, and specifically with the Game Matrix. We used a focus group of older adults to evaluate the games. Using a Grounded Theory to analyze the interview transcripts, we found a high level of engagement. Initially, they were attracted by the mission of the project and the possibility of helping themselves and other people. They continued using the games due to the games' supportive design.

Dedication

I would like to extend my heartfelt thanks to my supervisors, Dr. Christopher Anand, and Dr. Ian Bruce, for their invaluable guidance and support during my master's journey. Your expertise and encouragement have been instrumental in shaping my research and enhancing my academic experience. Thank you for believing in my abilities. Your dedication to my success has made a lasting impact on my journey.

I want to extend my heartfelt gratitude to my beloved better-half Nasrin and my parents for their unwavering support. Without your encouragement, navigating this journey would have been impossible.

Finally, I dedicate this thesis to my beloved grandmother, who passed away just a few weeks before my defence due to Parkinson's Disease. I hope the findings of this thesis pave the way for creating effective tools for the early detection of Parkinson's Disease, allowing other grandmothers to enjoy longer and healthier lives with their grandchildren.

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Definitions

MDS-UPDRS
The revision of the UPDRS, known as the MDS-UPDRS which is published by MDS in 2007.

UPDRS Unified Parkinson's Disease Rating Scale

Abbreviations

BG	Basal Ganglia
CNS	Central Nervous System
DA	Dopamine
DBS	Deep Brain Stimulation
EBR	Eye Blink Rate
EEG	Electroencephalography
ESM	Experience Sampling Method
FoG	Freezing of Gait
GABA	Gamma aminobutyric acid
GP	Globus Pallidus
HC	Healthy Control
MDS	Movement Disorder Society
MC	Motor Complication

ME Motor Examination

M-EDL Motor Experiences of Daily Living

nM-EDL non-Motor Experiences of Daily Living

PD Parkinson Disease

PNS Peripheral Nervous System

REM Rapid Eye Movement

SN Substantia Nigra

SNc Substantia Nigra pars compact

SNr Substantia Nigra pars reticulata

STN SubThalamic Nucleus

TC Tactile Cues

Chapter 1

Introduction

In the course of investigating Parkinson's Disease (PD), we discovered a gap between the technical capability of smartphones to collect data for screening and treatment monitoring, and the uptake of existing apps by older adults. In order to solve this problem, we conjectured that apps designed for both engagement and symptom monitoring could be more effective, especially if they are presented as games. Young adults and children are experts in gaming, but could they design games for older adults. To find out, we turned to Design Thinking (DT). DT is method of human-centered design with equal emphasis on problem definition and solution generation. It is very popular in business, see for example [10]. Although it has been applied in education, there is no consensus on how design tasks should be modified for young designers [20]: "Can young children engage in design and if so, what does that look like?" However, Dorie et al. [20] did find that even young children do engage in identifiable "problem scoping, idea generation, evaluation and revision," and "both predictive and reflective behavior." And this ability is inherent to most or all children. For example, Ehsan and Cardella [22] explore how a nine-year-old child with mild autism engages in problem scoping. The findings suggest that children with autism can participate meaningfully in engineering design, and that suitable activities and support can enhance their engagement.

Regarding undergraduate students, Abich et al. [1] explored the influence of Design Thinking (DT) on the collaborative skills of software engineering students. Their findings indicated that DT notably enhanced teamwork and problem-solving abilities. Additionally, Jiang and Pang [48] highlighted that combining DT with Project-Based Learning (PBL) greatly increased the learning motivation and creativity of engineering students. This approach fostered a more human-centered, goal-oriented, and empathy-driven mindset among students, leading to more innovative design processes.

Other educators have identified empathy as the key component of DT in education. McCurdy et al. [64] introduced the Problem-Based Design Thinking "(PBDT) Framework [...] an adapted version of the DT framework, a merging of DT ideas, problem-solving practices, and scientific thinking processes." The key feature of DT from their point of view is empathy, which was "the motor to engage students in the problem-solving task." They explain that without empathy "the other connections can become routine processes, and the task can simply become another in-class assignment."

We agree with the central role of empathy in the effective use of DT by young designers. Where we differ from typical DT methodologies is in the use of the Game Matrix for ideation and partly problem definition. The Game Matrix was observed by Dowlen [21] to be a misunderstanding of Morphological Charts. The basic idea is to encourage a wide exploration of the solution space by parametrizing it by two coordinates: PD symptoms and elders' interests.

Having decided to use DT to create prediagnostic games, we formulated two research questions:

1. Do young designers engage with the DT process, and make use of the Game Matrix, to create games appealing to older adults?
2. What key factors make digital games appealing to older adults, especially when these games aim to gather medical data for health monitoring or symptom tracking?

1.1 Background

Parkinson's Disease (PD) is a neurological disorder characterized primarily by four main symptoms: Tremor, Rigidity, Akinesia/bradykinesia, and Postural instability (often referred to as TRAP) [2, 26]. It is typically marked by a progressive loss of dopaminergic neurons within the substantia nigra pars compacta, which leads to dysfunction in the Basal Ganglia (BG) and affects motor and certain cognitive functions [86]. Recent research has also identified premotor symptoms such as Rapid Eye Movement (REM), sleep behaviour disorder, olfactory disturbances, constipation, vision problems, and mood changes including depression and anxiety, all of which may precede the onset of PD [37]. PD is the second most common neurodegenerative disorder worldwide, impacting approximately two percent of individuals over 65 years of age, four percent over 80 years, and more than one million people in North America [16, 54]. The exact causes of PD remain largely unknown, and there is currently no laboratory test to diagnose the condition, nor any cure available. While existing medications provide some symptomatic relief[1], none have been proven to slow disease progression. Levodopa is recognized as the most effective treatment; however, it is still uncertain whether its benefits come with neurotoxic consequences and long-term decline. A significant gap in PD therapy is seen in its more advanced stages, where several motor symptoms—including postural instability, dysphagia, dysphonia, and dyskinesia—are often inadequately managed by current medications [50]. Thus, early detection and ongoing monitoring of PD are of utmost importance.

Patients diagnosed with PD usually visit the clinic for severity estimation in their **off-time**. Off-time in patients refers to a period when the medication controlling their condition becomes less effective, leading to a gradual decrease in mobility [30]. Each person's understanding of **off-time** is shaped by their[2] perception of symptom severity. This understanding can pose a significant issue, as many patients may incorrectly interpret their symptoms as reasons to seek clinical evaluation. Furthermore, since early 2020, the frequency of clinical visits for regular severity assessments has declined, particularly among elderly patients who are at a higher risk of contracting COVID-19. Such patients may require additional hospitalization, intensive care, or even face life-threatening situations, especially if they have a chronic condition like PD. Thus, there is a pressing need for an effective tool that enables clinicians to monitor patients' conditions remotely, improving patients' daily quality of life while also conserving considerable resources within the healthcare system.

[1] `https://www.parkinson.ca/about-parkinsons/treatments/`

[2] To preserve the gender-neutral presentation, I am choosing to use "they/them/their" to address a generic third-person singular pronoun wherever it is necessary.

1.2 Research Motivation

Early detection of PD is vital for enhancing a patient's quality of life. A practical solution for monitoring PD symptoms involves utilizing smartphone apps for data collection alongside data-driven methods like Machine Learning (ML) models for assessing severity. As with any data-centric approach, challenges arise at every project phase, but the most critical stage is ensuring sufficient data collection.

Data collection methods for applying ML techniques in PD prediction and severity estimation primarily involve two categories: **invasive** and **non-invasive** tests. Invasive tests entail medical procedures that require clinicians to use instruments that cut through the skin or other connective tissues or penetrate the skin's lower layer. These tests necessitate the patient's physical presence in the clinic to obtain samples. Conversely, non-invasive tests are conducted without harming the subject, utilizing various tools. These tests can often be performed remotely and continuously while the subject engages in routine daily activities.

Certain apps collect data on PD symptoms remotely and non-invasively [8]. These apps track patients' symptoms using various modalities at least three times each day:

1. Before taking the medication (At their worst)
2. After taking the medication (At their best)
3. Sometime else.

One issue with this strategy is that most app users tend to disengage or withdraw their commitment over time. This often results in either no data being recorded after just a few sessions or only partial information being logged. Consequently, we are left with a dataset that has sparse entries from numerous users. A potential solution is to swap out the current apps for games designed to boost engagement while maintaining the data collection process over extended periods. While digital games are commonly thought to be more attractive and enjoyable for younger people, studies have demonstrated that older individuals also engage in and derive pleasure from games [18].

A significant challenge when designing games for older adults lies within the design process itself. Human-centered design methodologies are highly effective for creating products tailored to a specific audience. A particularly promising method for human-centered design is co-design, which emphasizes collaboration and harnesses collective creativity throughout the design journey [82]. The purpose of co-design is to enhance product quality, ensure better alignment between functionalities and user needs, and boost overall user satisfaction [99]. Design Thinking (DT) is a structured, human-centered approach to problem-solving that emphasizes understanding user needs, creating a variety of innovative solutions, and continually improving those solutions through iteration [10]. Researchers have studied the design of digital games for older adults [46, 61] and have identified related challenges [33, 41]. Nonetheless, there has been little focus on co-design in general and design thinking in particular for creating games aimed at older adults, especially when the primary goal of these games is health monitoring and symptom tracking.

1.3 Scope and Structure of the Research

This research focuses on improving older adults' interaction with applications by replacing them with games specifically designed for this demographic. Additionally, we aim to determine the elements that make games egnaging for older adults, particularly when the primary goal of these games is to collect medical information or track disease symptoms.

Building on this, our focus will be on:

- Outlining a design methodology based on DT for designing games for older adults.
- Secondly, exploring the elements that enhance the engagement of games, especially when their main goal is to collect data for medical purposes.

This thesis is organized as follows. Chapter 2 discusses PD, focusing on its symptoms and physiological components. Chapter 3 introduces the concept of remote, noninvasive monitoring for PD. Chapter 4 describes human-centered design for older adults, along with design thinking and morphological charts. In Chapter 5, we outline our methodology, followed by Chapters 6 and 7, where we present the outcomes of this research. We conclude the thesis with Chapter 8.

1.4 Summary of Contributions

1. Development of the Game Matrix ideation activity within DT to increase the number and diversity of ideas, especially among new designers.
2. Designing a number of games based on the interests of older adults with game mechanics designed to measure specific PD symptoms.
3. Identifying factors that boost engagement among older adults with these types of games.

Chapter 2

Physiological Background

This chapter presents the physiological system associated with PD and its connection to various symptoms. This insight enhances our understanding of the goals behind the games we created.

2.1 Nervous system

The nervous system is a network that consists of complicated cells called neurons. Neurons are responsible for accommodating actions and transmitting signals between different parts of the body. The nervous system is accountable for coordinating movements, processing input from the senses, and other cognitive functions.

According to most neurologists, we can split up the nervous system into two main parts. The Central Nervous System (CNS) is the brain and spinal cord, and Peripheral Nervous System (PNS), which is the rest of the system. In this study, we are interested in CNS; since pathophysiologically, it is the nerve center of the PD. Thereupon, we introduce the physiology of the brain, neurons and the glia, and different parts of the brain affected by PD. We encourage the interested readers to refer to [40] for more detailed information about the physiology of the nervous system.

2.2 Physiology of the neurons

A neuron consists of the soma, or cell body; an axon, which is an electrically conducting fiber; and dendrites that receive signals from other neurons, as illustrated in Figure 2.1.

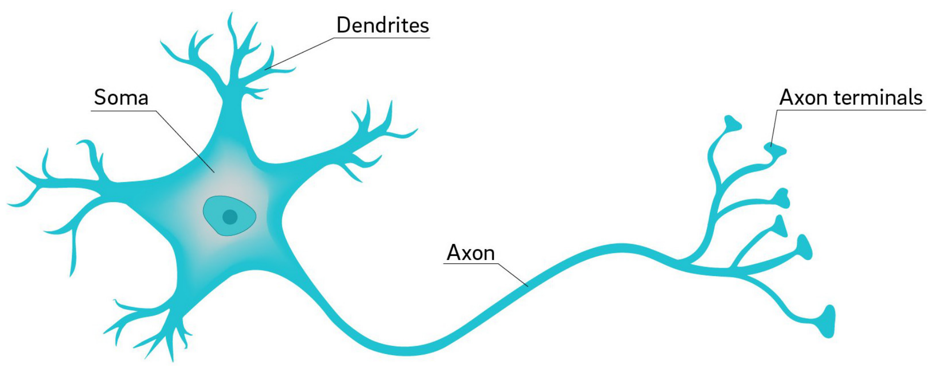

Figure 2.1: A neuron and its main anatomical parts. Credit: David Baillot/ UC San Diego

Neurons communicate with each other by transmitting electrical impulses, also known as nerve impulses, which occur when a small current flows along the axon. When a stimulus reaches a level of 15 mV above the normal resting voltage of -70 mV, it generates a nerve impulse. This stimulus initiates both electrical and chemical changes within the neuron. There are various ions located on either side of the cell membrane; the outside contains a higher concentration of positively charged sodium ions, while the inside is characterized by a negative charge due to the predominance of potassium ions. This imbalance in charge creates an electrochemical gradient.

When a nerve impulse is triggered, the cell membrane's permeability changes. Sodium ions enter the cell while potassium ions exit, leading to a reversal of electrical charges. As a result, the cell becomes depolarized, generating an action potential that propagates the nerve impulse along the axon. This depolarization happens sequentially along the nerve. A series of reactions follow, where potassium ions re-enter the cell and sodium ions leave, restoring the cell's polarized state by re-establishing the original charge distribution.

When a nerve impulse arrives at the axon's end, it triggers the release of neurotransmitters. These chemicals diffuse across the synaptic gap, the tiny space between the axon and the receptors. Nerve impulses can be conveyed through either electrical synapses or the chemical synapse. Figure 2.2 depicts this process.

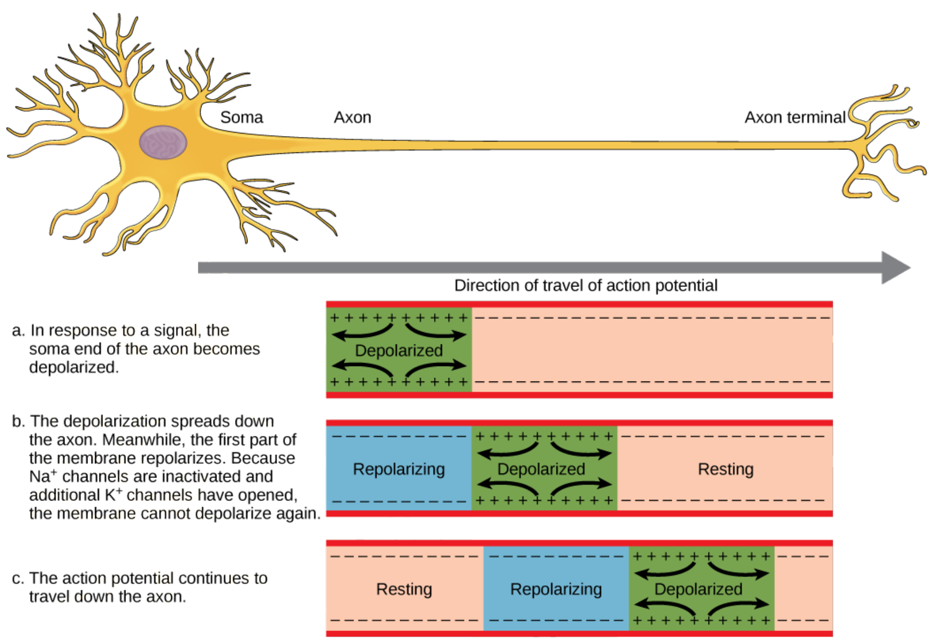

Figure 2.2: The action potential travels along the axon while the axon membrane first depolarizes and then repolarizes. [66]

2.3 Basal Ganglia

A discussion of the important role the BG plays in PD, must center on the neurotransmitters *Dopamine (DA)* and *Gamma AminoButyric Acid (GABA).*

DA is highly concentrated in the Substantia Nigra (SN), one of the basal ganglia's (BG) outputs, and it projects extensively to the Striatum, which serves as the BG's input structure. [1] Dopamine is essential for both motor and cognitive functions through its actions on specific receptors [45]. These receptors are classified into two main types: the excitatory **D1** and the inhibitory **D2** receptors. A depletion of DA can lead to significant motor dysfunction linked to the BG. Additionally, GABA, an inhibitory neurotransmitter, is mainly found in the medium spiny neurons within the striatum.

The **Striatum** serves as the input structure of the BG. The striatum transmits inhibitory signals using GABA to both parts of the globus pallidus. The **Globus Pallidus (GP)** serves as the output structure of the BG, and transmits inhibitory signals to the thalamus via GABA.

The **SN** serves as an output of the BG structure. It has two components: the Substantia Nigra pars compacta (SNc) is the striatum's main source of DA; and the Substantia Nigra pars reticulata (SNr) is primarily engaged in transmitting GAGA to the superior colliculus, which is involved in the control of eye movements.

The **Thalamus** serves as a central hub in the brain, transmitting signals between the subcortical regions and the cortex. In relation to the BG, inhibitory signals from the SN and GP are directed to the thalamus, which subsequently communicates with the motor cortex.

[1] Definitions of SN and Striatum will be provided later in this section.

The **SubThalamic Nucleus (STN)** is crucial for regulating the output of the BG by stopping the early disruption of one plan by the introduction of another plan into the BG.

The BG regulate behavior through normally-closed gates. To implement this strategy, they are recognized to have two main pathways called nigrostriatal pathways. (see the diagram in Figure 2.3):

- Direct pathway: cortex → striatum → GPi/SNpr → thalamus (activated when a plan is executed)
- Indirect pathway: cortex → striatum → GPe → STN → GPi → thalamus (activated when a plan is deferred)

In humans, the nigrostriatal pathway, which involves the projection of dopaminergic neurons from the substantia nigra pars compacta to the dorsal striatum, is crucial for regulating motor functions and learning new motor skills [68]. These neurons are particularly susceptible to injury, and a significant loss of these cells leads to the development of Parkinson's syndrome [14].

2.4 Parkinson's Disease

The exact causes of Parkinson's Disease (PD) remain unclear [54]. However, it is understood that a decrease in dopaminergic neurons leads to dysfunction in the BG, which plays a crucial role in regulating both motor functions and certain cognitive abilities [86]. This dysfunction contributes to the manifestation of PD symptoms. Dopaminergic neurons facilitate communication between other neurons, and their depletion disrupts the CNS, impairing the ability to coordinate muscle movements

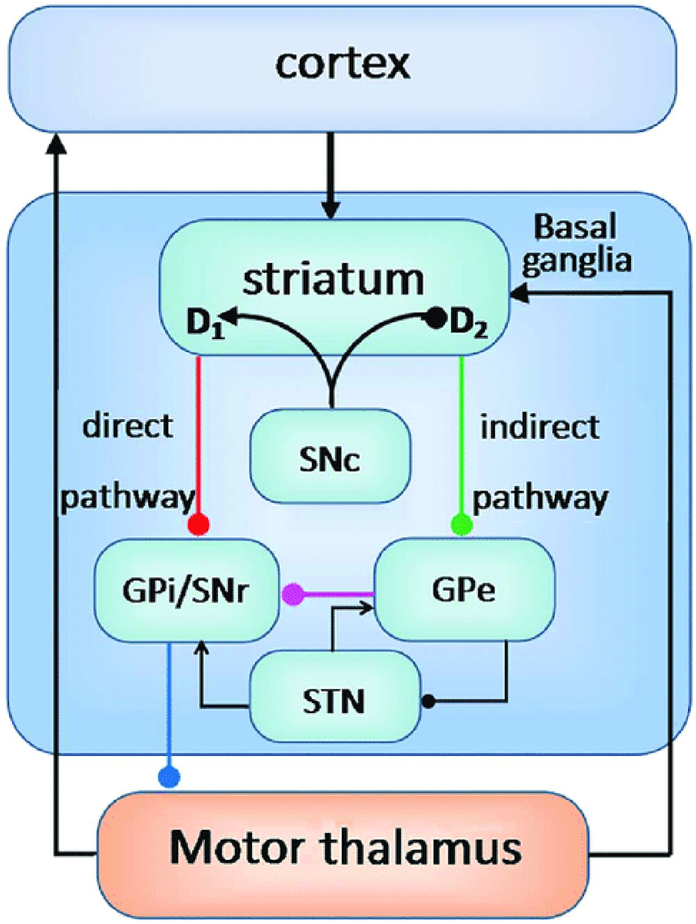

Figure 2.3: Schematic diagram of the BG [32]

effectively. Noticeable clinical symptoms typically arise when the disease has significantly progressed, at which point approximately 60 to 80 percent of dopaminergic neurons have already been lost, making it too late to halt the degeneration [7]. The advancement of the disease correlates with the ongoing loss of dopaminergic neurons, leading to increasingly severe symptoms, such as tremors and impaired muscle control.

Tremor, rigidity, and disordered movements are the main symptoms. At first, symptoms are often asymmetrical, favouring one side of the body, which indicates ath one hemisphere's BG is facing larger dopaminergic loss. However, eventually, it will proceed bilaterally.

There is no accord among neurologists on diagnosing a person with PD, which is the reason for many incorrect diagnoses [54, 71]. De Rijk et al. concluded that a subject exhibiting two out of the three main symptoms should be diagnosed with PD [17]. But if they have a history of essential tremor, all three symtoms are required [77]. Even though pathophysiological classification of subjects is notably hard; however, it is clinically valuable and facilitates better treatment [71].

To quantify and monitor the PD progress, it is necessary for the patient to participate in a range of physical examinations designed to test the subject's ability to perform a range of tasks. The MDS-UPDRS [36] is the standard reference scale approved by MDS. The MDS-UPDRS is made of 50 different sections, where each section groups observations related to one part of the body. The score for each range is between 0 to 4, in which 0 denotes no symptoms and 4 is a clear indication of impairment. The accumulation of scores gathered from different sections will produce the total-UPDRS score. This score ranges from 0 to 199, of which 0 represents no disability and 199 total disability.

It is possible to extend the life expectancy of PD patients significantly. Parients reaching age 60 have an expected life expectancy of 20 additional years [71]. Pharmaceutical [2] and Deep Brain Stimulation (DBS), which is surgical intervention [5] are reported to reduce tremor and enhance motor functionality, delaying disease progression and offering reasonable good life quality. Therefore the detection of disease in the early stages is vital for increasing the life expectancy of patients.

[2] A combination of Levodopa and other agents

2.5 Parkinson Symptoms

To make sure that the general readers have a general understanding of the effects PD has on the human body, it is better to describe its symptoms briefly. As also stated before, PD symptoms are tremor, bradykinesia, postural instability, and rigidity are the main motor symptoms. Patients also experience non-motor symptoms such as dysarthria, sleep disorders, and cognitive and vision impairments [60]. Since some of the terminologies we introduce above are not familiar for a general reader, it is better to describe them briefly. This will also help us to expand them later when we introduce the modalities we are going to use for PD detection/estimation.

Tremor is a rhythmic shaking movement in one or more parts of the human body. It is involuntary, which means that one cannot control it [23]. There are different kinds of tremors. The one that is of interest for us is the parkinsonian tremor. It is thought oscillations originate in the BG within a topographical loop which then propogate to the muscles [19]. Micrographia is one of the disorders that shows the effect of the tremor in a patient's body. It is "an acquired disorder that features abnormally small, cramped handwriting or the progression to smaller handwriting." [43] Figure 2.4 depicts a sample of Micrographia. It is clear that the tremor of the hand affects the normal handwriting of the subject.

Bradykinesia is the slowness of movement, one of the main signs of PD. This slowness happens in different ways [6]

However, symptoms of Bradykinesia is not limited to slowness. We can list the following symptoms also indicators of Bradykinesia [12]:

- Shuffling when walking.

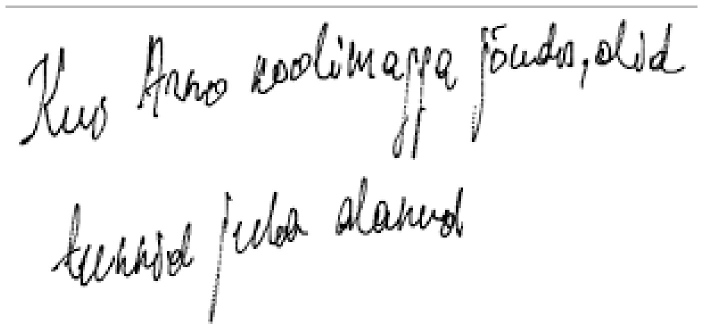

Figure 2.4: Example of Micrographia as the result of PD [69]

- Dragging one or both feet when walking
- Having little or no facial expressions.
- Difficulty with repetitive tasks.

As some examples of Bradykinesia, we can mention Hypomimia and Eye Blink Rate (EBR). Hypomimia is the clinical term for a loss of facial expression. Decrease mobility in the muscles of the face is the major symptom of this disorder [78]. Figure 2.5 shows an example of a person with Hypomimia. EBR is clear and does not need further explanation. Clearly decrease in the blinking rate is an indication of slowness in movements.

Dysarthria arises when the muscles used for speaking are weak or when there is difficulty in controlling them. This condition typically results in speech that is slurred or slow, which can make it hard to comprehend. [15].

Figure 2.6 depicts two Speech traces and Spectrograms of two subjects. The images on the right belong to a Healthy Control (HC) woman with 34 of age and the images on the left belong to a PD woman with the age of 72. Both subject utterance five cardinal vowels [a:],[e:],[i:],[o:], and [:u]. The voice samples were recorded at 8 KHz and 16 bits and filtered to remove the insufficient glottal residual (glottal pulse)

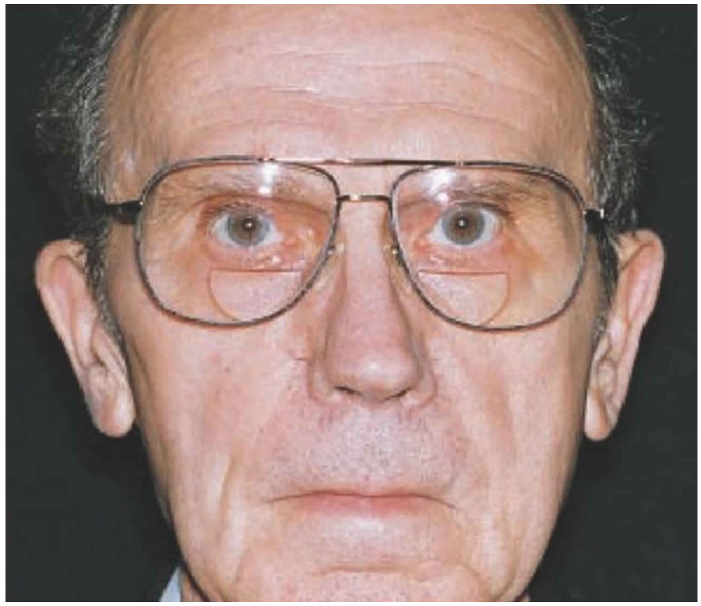

Figure 2.5: Example of a face with Hypomimia
from: https://healthjade.net/hypomimia/

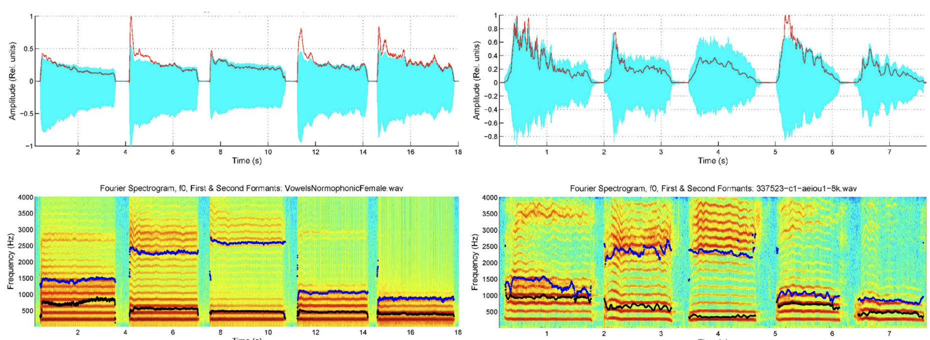

Figure 2.6: Examples of voice impairments as early symptoms of PD. [38]

effect which is the variance in voice quality affected by the manipulation of the folds of the vocal cords when speaking. Relevant tremor and articulation instability can be clearly appreciated in both harmonics and formants in the spectrogram as well as in the energy envelop (Red).

Chapter 3

Remote Non-Invasive Parkinson's Disease Monitoring

While there are benefits to remotely monitoring PD, challenges and limitations also exist. Before detailing our approach, it is valuable to examine prior research on remote data collection for PD. Understanding the functionality of these applications will aid in clarifying the objectives of our study.

3.1 Remote Monitoring of PD and Its Challenges

All existing publications can be categorized into two primary groups. The first group consists of research projects that utilize costly medical devices like wearable accelerometers or Electroencephalography (EEG) [74, 84, 92, 75, 83, 4]. Typically, the data for these studies is gathered under clinical conditions [74, 84, 4], which may not accurately reflect the experiences of patients with PD in their everyday lives. Another challenge is the limited number of volunteers involved in the research. Due to the constraints mentioned, participants need to be present in a clinical or research setting for data collection, leading to insufficient recorded data in these projects. Additionally, the demographic profiles of participants often do not adequately represent the wider population living with PD.

The second group of studies focuses on monitoring only one aspect of PD. Examples of such published reports include but are not limited to studies addressing dyskinesia [92], gait disturbance [75, 63, 4, 97], and voice impairments that could be detected at the early stages of the disease [91, 90].This also decreases the reliability of the reported results since PD is a multi-faceted disorder.

The second group of studies concentrates on monitoring a single aspect of PD. Published reports in this category include research on dyskinesia [92], gait disturbances [75, 63, 4, 97], and early-stage voice impairments [91, 90]. This narrow focus diminishes the reliability of the findings, as PD is a complex disorder with multiple facets.

A similar trend emerges when evaluating apps aimed at remote monitoring of PD. Two systematic reviews focus on mobile phone apps for monitoring and managing the disorder.

In the first study, Sonia et al. [25] focused on conducting a systematic review of apps related to PD for the iOS and Android platforms, aiming to assess the usability of these apps. After screening, they identified a total of 92 apps: 38 for Android, 38 for iOS, and 16 compatible with both operating systems. Their analytical results are presented based on the apps' distribution according to symptoms, movement issues, purposes, target users, and costs in each marketplace. Their results indicate a greater number of apps centered on symptom monitoring than those aimed at specific symptom treatment. Furthermore, many apps target the four main symptoms of PD (TRAP: tremor, rigidity, akinesia/bradykinesia, and postural instability). The findings suggest that while every distinct symptom of the disease is managed by at least one app, no single app offers comprehensive coverage for all symptoms.

The results of the second study also align with those of the first study. Rey et al. [57] conducted a systematic review of literature that is directly or indirectly relevant to PD and managing its symptoms. They took a different approach, examining not only the types of symptoms but also the types of sensors in smartphones used for data collection. They concluded that, despite existing evidence, the poor methodological quality of the reviewed studies hinders their ability to recommend widespread use of these apps. They suggested further research into the benefits and risks associated with mHealth in this area. Table 3.1 lists the key publications mentioned by [57], arranged alphabetically. Additionally, we have updated this table to include new findings.

Table 3.1: Smartphone apps active in the area of PD assessment or measurment

Publication	App Name	Participants	Measurements
Arora et al. [3]	Pilot study for HopkinsPD	20	Voice, Posture, gait, finger, tapping and response time
Bot et al. [8]	mPower	9520	Voice, Walking, Tapping, Visual Memory
Casamassima et al. [13]	[Not mentioned]	0	Gait spatio-temporal features
Ellis et al. [24]	SmartMOVE	24 (12 HC + 12 PD)	Gait features using two contact-base measurement devices
Ferrari et al. [27]	[Not mentioned]	28 (12 HC + 16 PD)	Gait spatio-temporal features (Additional sensors required)
Ferrari et al. [28]	SENSE-PARK System	22 (PD)	Motor related raw data (Additional sensors required)
Fraiwan et al. [29]	Sensor UPD	42 (21 HC + 21 PD)	Tremor recording using Mobile accelerometer

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Publication	App Name	Participants	Measurements
Ginis et al. [34]	CuPiD-system	40 (PD)	balance,gait,endurance,and quality of life. (Additional sensors required)
Ivkovic et al. [47]	[Not mentioned]	20 (10 HC + 10 PD)	Gait features based on Tactile Cues (TC) (Additional sensors required)
Kim et al. [49]	[Not mentioned]	15 (PD)	Accelerometer and gyroscope for gait feature recording
Kostikis et al. [51]	Tremor Sence	20 (10 HC + 10 PD)	Accelerometer for recording the tremor (Web base)
Kostikis et al. [52]	Tremor Sence	23 (pd)	Accelerometer and gyroscope for recording the tremor (Web base)
Kostikis et al. [53]	Tremor Sence	45 (20 HC + 25 PD)	Accelerometer and gyroscope for recording the tremor
Lee at al. [56]	[Not mentioned]	103 (PD)	No sensor applied
Lopez et al. [59]	Listenmee	10 (PD)	Gait features (Additional sensors required)
Palmerini et al. [72]	[Not mentioned]	49 (HC)	Accelerate for Timed and Go test
Pan et al. [73]	PD Dr	40 (PD)	Accelerometer for tremor and gait features
Printy et al. [76]	Bradyapp	26 (PD)	Accelerometer and gyroscope for tracking bradykinesia
Sama et al. [81]	REMPARK	40 (PD)	Accelerometer and gyroscope for gait assessment (Additional sensor required)
Takac et al. [89]	[Not mentioned]	12 (HC)	Accelerometer and gyroscope for Freezing of Gait (FoG)
Van der Kolk et al. [93]	Park-in-Shape	130 (PD)	Tracking the sport activity for PD patients using smartphone sensors.
Wanger and Ganz [95]	PAGAS	Not reported	Gait features gathering based on footwear (Additional sensors required)

The initial issue with the results presented in Table 3.1 is that many apps rely on a single sensor or gather data concerning just one symptom. Additionally, the second concern pertains to the number of participants involved in the apps' validation process. This connects to the earlier issues we mentioned regarding the reliability of the findings.

The most significant initiative to tackle these issues was put forth by Arora et al. [3]. In their preliminary study, they focused on the challenges arising from the multi-faceted aspects of PD and aimed to address this by collecting data based on various symptoms. By gathering voice recordings, analyzing how subjects interacted with the phone screen, as well as utilizing data from accelerometers and gyroscopes, they sought to explore the potential for remotely monitoring multiple symptoms of PD through just a smartphone. However, their study was limited by the number of participants involved.

Later, they increased the number of participants to 226 (121 PD, 105 HC) to validate their approach with more reliable data. They also named their app **"HopkinsPD"** and made it available for download in the Google Play Store, and described the overall process of extracting statistical features from the raw data they collected. [100]. This paved the way for introducing a new severity measurement score called MPDS [101], where they applied the app to generate an objective score based on the sensor data. Yet, there is a limitation that has emerged here as well. Even though MPDS is derived from 6148 smartphones, the participants were generally white, college-educated, and from households that owned Android smartphones, and thus were not representative of the broader PD population. Moreover, the overall number of participants was 129 individuals, with only 23 PD and 17 HC completing the in-clinic assessment. Therefore, the problem of having not enough participants with good diversity remains an issue to address. Nevertheless, to our knowledge, this is among the largest long-term smartphone assessments of PD.

Perhaps the most comprehensive and successfully researched work addressing the multifaceted nature of PD and involving a diverse range of participants is that conducted by Bot et al [8]. The mPower app, which is the iOS version of HopkinsPD, is designed to collect smartphone sensor data through four tasks aimed at gathering voice, tapping, walking, and visual memory data. Employing the feature extraction methods introduced in the study by Zhan et al. [100], data was collected from 9,520 subjects and made accessible through Sage Bionetworks, a nonprofit organization in Seattle that fosters open science and patient engagement in research, spearheaded by Lara Mangravite and co-founded by Stephen Friend and Eric Schadt. This dataset is unique, as it can be utilized for calculating scores such as the MPDS and for long-term monitoring of the disorder. However, the dataset's limitation lies in the compromise of data accuracy, as it lacks precise annotations. Besides the basic binary annotations indicating PD or Healthy Control (HC), records were also labeled according to the MDS-UPDRS. Since completing the MDS-UPDRS form requires nearly two hours, neurologists administer it to each patient only once every three months. Consequently, mPower records only sections of the MDS-UPDRS form based and created based on the subjects' self-reported assessments of their status. In other words, the score is derived from the subjects' perceptions of the severity of their symptoms, which has led MDS to deem this MDS-UPDRS score as unreliable.

To the best of our knowledge, Rueda et al. [80] are the only researchers addressing the aforementioned annotation issue. In the absence of standard severity labels, they extracted features from the voice recordings of subjects in the `mPower` dataset and employed various unsupervised clustering methods to explore the similarities within the recorded data. They then attempted to estimate the number of clusters, denoted as K, using statistical and direct approaches. Their experiment's results indicate that the estimated K does not align with the UPDRS Speech scales. Nonetheless, they identified three distinct clusters: severely impaired voice, mildly impaired voice, and healthier voice.

3.2 Conclusion

In this chapter, we explored significant literature regarding remote monitoring of PD. The most significant issue is the number of volunteers participating in the research process. Arora et al. [3] attempted to tackle this challenge. However, findings from [80] indicate that there is a serious issue with data annotation, not only in the `mPower` project but also in other datasets utilizing similar methodologies. This may arise from two factors. The first factor is the scale employed for data annotation, which lacks full approval from MDS. The second factor from our investigation reveals that, despite the substantial volume of data collected following the approach of Arora et al. [3], the project faces challenges related to participant engagement and commitment to the app. This is what we are trying to address in our study.

Chapter 4

Human-center Design Methodology for Designing Games

4.1 Introduciton

According to United Nation Population Prospect, “by 2050, 1 in 6 people in the world will be over the age of 65, up from 1 in 11 in 2019.” [70] Additionally, the elderly of the future are expected to lead healthier lives, resulting in a longer life expectancy and higher levels of education [85]. As a result, older adults are becoming an increasingly important user group for technology, with their own distinct needs and challenges [42, 94]. This presents new opportunities for technological solutions tailored to their specific needs, including health and social connectedness [58, 67, 79].

While digital games is commonly thought to be more attractive and enjoyable for younger people, studies have demonstrated that older individuals also engage in and derive pleasure from games [18, 39]. They also express interest in playing games when they perceive it as a cost-effective way to support their health and enhance their overall well-being [9, 33, 55]. Scholars have conducted numerous reviews focusing on the various uses of serious games to improve cognition, rehabilitation, social interactions, physical activity, engagement, as well as overall health and well-being. These studies explore how serious games are employed in different fields to positively influence mental and physical wellness, social connections, and overall quality of life [98, 62, 102], as well as the impacts of games for older adults on physical and cognitive abilities [102, 39, 65].

Co-design involves the collaborative process of designing, utilizing combined creativity throughout the design process [82]. The use of co-design or human-centered design aims to produce higher quality products, better alignment between the product's functionalities and the users' needs, and increase user satisfaction [99]. Researchers have studied the design of digital games for older adults [46, 61] and have identified related challenges [33, 41]. Nonetheless, the co-design approach in developing these games has received little attention. This chapter delves into DT as one of the well-known human-centred methodologies for investigating problem and solution spaces, and morphological charts. We will cover the advantages and disadvantages and explore ways to address possible challenges using recommendations from the literature.

4.2 Design Thinking

The DT journey begins with the Empathize phase, which serves as the cornerstone of design thinking. The objective is to deeply understand the needs, desires, and behaviours of the target group for whom we are designing. Empathy not only clarifies the underlying motivations of users but also helps designers detect hidden assumptions. By becoming immersed in the user's perspective, design solutions can address real problems rather than superficial symptoms. In the context of our research, the objective is to grasp how to design engaging games for older adults, implemented via interviews and feedback loops with target user groups. The goal is to identify the interests of older adults that can inform the subsequent stage of developing game concepts. The result of the analysis could potentially show how older adults interact with technology, the types of games they enjoy, their preferred activities, and any other insights that can help game designers create games tailored to this demographic.

In the second stage, Define, the goal is to synthesize insights from the Empathize phase and create a clear, actionable problem statement. This stage transforms user insights into a design challenge, sharpening the focus on the actual issue rather than its symptoms. A well-defined problem sets the stage for innovative and relevant solutions. Next comes the Ideation stage, aimed at generating a broad range of potential solutions and questioning assumptions through divergent thinking. A fundamental principle of design thinking is to scrutinize preconceptions and investigate various solution avenues before settling on one option. The Ideate phase is intentionally broad in scope: both the quantity and variety of ideas are crucial, as even the most unconventional concepts can lead to more polished solutions afterward. This is followed by the Feasibility vs Desirability worksheet, which will give the team the list of potential games to design and prepare for the next stage.

The subsequent phase, Prototyping, is instrumental for design teams as it facilitates the creation of tangible representations—at various levels of fidelity—of the concepts formulated during the Game Matrix stage. Prototypes serve to materialize ideas, enabling designers and relevant user groups to assess feasibility at an early stage. By transforming abstract concepts into concrete forms, teams are afforded the opportunity to refine details, eliminate ineffective paths, and communicate potential outcomes more effectively. This phase advocates for iterative cycles of build-measure-learn. Within the scope of this research, the design teams will produce two paper-based prototypes of the intended games utilizing the worksheets at their disposal. This process will prepare them adequately for the subsequent stage of testing the games.

The final test stage involves evaluating prototypes in real-world settings, typically by actual users. The objective is to validate the prototypes through user feedback and refine solutions based on real-world interactions. Testing effectively closes the design thinking loop by bringing the process back to the user. This stage is fundamentally iterative: if new insights surface, teams often return to earlier stages (e.g., revisiting game ideas in the Game matrix or prototype) to incorporate the feedback. In the context of this research and our worksheets, this feedback manifests as action plans that assist the design team in revising their ideas based on the feedback received. This continual cycle of testing and refining is essential for achieving a solution that is genuinely human-centred.

4.3 Morphological Charts

"A morphological chart is a tool that represents a large qualitative design space. These charts list the functions identified for [a] design problem and the means (solutions) that can perform each function." [88].

A morphological chart is a compact representation of a large disconnected design space, meaning that the design space is not simply a tuning of numerical parameters, but the result of many independent descisions about the means of solving a subproblem. Prototypically, the problem is a mechanical eningeering problem with distinct parts or subassemblies. [88].

- **Functions:** represent the connections between a system's inputs and outputs. Generally, they form a pair made up of an action verb followed by a noun.
- **Means:** are the solutions to a specific function. Various terms exist for these solutions, such as working principles or design parameters.

The number of possible combinations is the product of the number of means of implementing each function. Even a design with four functions and ten means of imlementing each would result in 10K designs. Morphological charts are usually displayed as a (staggered) table. The first column lists the functions, and additional columns list different means, which may vary in number per funciton. Rather than looking for a target number of means, the design should look for a consistent level of specification in each of the means.

Morphological charts are valuable tools for designers when exploring open design spaces and aiming to systematically generate concepts. They can reveal surprising combinations of features, inspiring new ideas, and offer a comprehensive view of the overall design landscape. Nonetheless, producing an extensive range of options can present challenges.

4.4 Morphological Charts and Design Thinking

Morphological charts are a design tool arising in mechanical engineering. These charts, essentially tables of **functions** and corresponding solution **means**, offer a systematic way to explore a design space, fostering creativity and helping designers to navigate complex problems. However, the effective use of morphological charts requires a deep understanding of their limitations, as well as the broader principles of design.

At their core, morphological charts align with DT's emphasis on structured problem-solving. By breaking down a design challenge into its core functions, designers can then explore various means to achieve each function [88, 87]. This systematic decomposition and recombination of elements allows for a comprehensive exploration of the design space, revealing potential solutions that might not surface through less structured approaches. This is aligned with the concept of divergent thinking, where the objective is to broaden the solution space as much as possible [87].

However, the very strength of morphological charts—their ability to generate a multitude of combinations—can also be their weakness. As the number of functions and means increases, the resulting design space can become overwhelmingly large, leading to analysis paralysis and reduced efficiency. This is a common challenge in DT, where expansive ideation needs to be followed by strategic convergence [88, 87]. For example, George et al. in their works notes that a small design task with 5 functions and 10 means per function results in 100,000 combinatorial possibilities, making it impractical to explore them all [31]

Several studies have addressed the challenge of managing the complexity of morphological charts. The experimental research presented in both Smith's thesis and the subsequent journal article underscores that reducing the number of functions while maintaining a good selection of means can significantly improve the quality of the conceptual design chosen. This suggests that excessive functional decomposition is not always beneficial and can even hinder the design process. These findings align with DT principles that emphasize the need to focus on core issues rather than getting lost in excessive detail [88, 87]. Moreover, this research suggests that broadening the design space by incorporating a larger variety of means for each function is advantageous. This approach grants designers more options and combinations to consider. Nonetheless, as highlighted by George et al. [31], Smith's studies also indicate that beyond a certain point, adding more means may not enhance concept quality significantly, thus underscoring the necessity for a more balanced and considered strategy.

While morphological charts offer a powerful framework for idea generation, it is important to recognize that they are not the only tool in a designer's toolkit. The studies reveal various ways that morphological charts can be used in combination with other methods, including:

- **Options Matrices:** George et al. introduce the concept of options matrices, which focus on combining means for closely coupled functions, allowing for a more detailed exploration of sub-system level concepts. This approach aligns with the DT principle of focusing on specific problems and challenges within the larger design space [31].

- **Functional Modeling:** Caldwell's work emphasizes the importance of functional representations in design, showing that pruned function models, which focus on high-level core functions, can improve both understanding and idea generation. This approach complements morphological charts by providing a more structured method for defining the functions used in the chart [11].

- **Crowdsourcing:** Huang et al.'s work on crowdsourcing presents an interesting, alternative approach to ideation, using external sources for generating and mapping ideas. While not directly related to morphological charts, this method demonstrates that diverse inputs and structured analysis can be used to comprehensively explore a design space [44].

Morphological charts, when properly applied, can drive design innovation by helping designers identify unexpected combinations of means. By systematically exploring all possible combinations, designers are more likely to discover novel and creative solutions that might have been overlooked with more intuitive methods. This structured approach encourages designers to push the boundaries of the design space and consider unconventional solutions. In this way, morphological charts are not merely a tool for combining existing ideas but are also a means for generating completely new concepts [96, 31].

4.5 Conclusion

In conclusion, morphological charts serve as valuable tools for exploring design spaces, but it's essential to understand their complexities. When function decomposition and means selection are thoughtfully considered, and when used alongside other design tools, these charts can significantly enhance the DT process, promoting innovation and resulting in high-quality, human-centered solutions.

Chapter 5

Research Methodology

This chapter outlines the methods and procedures used in this study to evaluate engagement and identify design elements relevant to games created for the remote monitoring of chronic conditions, specifically PD. Data collection took place in November 2024, involving eight older adults who participated in the evaluation and following focus group at McMaster Campus to assess the games aimed at detecting PD.

This chapter provides a detailed overview of the methods used in game design, along with the qualitative and quantitative techniques employed for evaluation, including pre- and post-experimental surveys and focus groups. It is divided into two main sections. First, we explore DT and how we applied it as a user-centred design methodology to create and implement game mechanics for older adults. Next, we discuss Grounded Theory as the evaluation methodology, identifying the design factors that contribute to successful game designs intended for medical purposes for older adults.

5.1 Research Design Overview

The primary objective of this project is to develop a multimodal machine learning model specifically designed to detect PD using publicly available datasets. These datasets are derived from data collected through mobile applications implemented for this purpose. However, after gaining access to the data and conducting preliminary analyses, we found that the quality of the data was not as expected previously.

The target application users are required to input their data regarding five distinct tasks three times daily: once prior to medication administration, once post-medication, and once at an unspecified time between these two events. By correlating the collected data with the users' Unified Parkinson's Disease Rating Scale (UPDRS) scores, substantial information regarding the patterns of symptoms in relation to the types and dosages of medications could be obtained. This analysis eventually aims to evaluate the effectiveness of treatment in enhancing the quality of life for patients. Additionally, it seeks to provide significant insights into the potential manifestation of PD symptoms in the healthy control group utilizing the application.

After gaining access to the data, we commenced our primary analysis, which revealed that the majority of app users, regardless of their classification as HC group of PD patients, discontinued usage after just two weeks of data submission. This raised a crucial concern: the quality of the collected data appears insufficient for any data-driven approaches. Consequently, we recognized the importance of designing data collection applications that keep users engaged over longer periods, ensuring that the quality of data gathered is adequate for subsequent analysis. Thus, the project's objective became clear: to create games that engage older adults, enabling them to spend time in the app while we collect data in the background. We named this initiative “This is your grandfather’s gaming app.” The project consists of two phases: the first phase focuses on creating games specifically tailored for older adults, and the second phase involves ensuring that the design sufficiently engages this demographic. This led us to choose a methodology for app design and evaluation of both engagement and design quality. For the initial challenge, we opted to employ Design Thinking, a well-known user-centered iterative problem-solving approach, to develop the game mechanics. Additionally, we will use Grounded Theory, supported by pre- and post-experiment surveys, to measure the design quality developed through the Design Thinking approach.

5.2 Design Thinking

In Section 4.3, we introduced various stages of design thinking (DT) and emphasized the relationship of morphological charts to DT in Section 4.4. In this section, we will outline our methodology that leverages both DT and morphological charts.

In the second phase of DT, after discussing our expectations with the designers regarding the problem and possible solutions, simply following the standard phases—defining the problem and ideation—did not suffice for them to create effective solutions. Consequently, we developed a fresh approach to replace the problem definition and ideation stages.

We created the **Game Matrix** to tackle the identified limitations in examining the problem or solution space before settling on a particular problem or solution. The Game Matrix is organized around two axes, offering non-overlapping perspectives on the issue and ideally aligning with the design teams’ research concerning the problem or insights from initial interviews. In relation to the PD issue, the matrix columns represent symptoms, while the rows illustrate user interests derived from the interviews. The number of rows and columns can be adjusted according to the specific problem; however, based on literature recommendations and our observations, we have opted for four symptoms times four interests. This configuration will yield 16 unique gaming ideas, which will serve as solutions to further investigate within the DT design process as outlined in Section 4.3. Figure 5.1 provides an example of our Game Matrix.

Figure 5.1: The Game Matrix

	SymptomA	SymptomB	SymptomC	SymptomD
Interest 1				
Interest 2				
Interest 3				
Interest 4				

The Game Matrix may be confused with a morphological chart. However, as explained in [16], novice designers often misunderstand the concept and generate variations on this chart. Adhering too closely to a standard morphological chart can lead to an overwhelming number of ideas, as discussed in the literature referenced in Section 4.4. This approach contradicts the goals of Design Thinking (DT), where designers should eventually converge and concentrate on developing a selective list of ideas. Standard morphological charts can also restrict creative exploration, by focusing on functional components based on an initial decomposition of the solution into components. This may make sense for many mechanical engineering design problems, but it is too restrictive for our problem. Our aim is to encourage designers to explore the design space freely for game concepts that resonate with the interests they identify during their research, which is not possible with traditional morphological charts. Nonetheless, grasping the idea behind morphological charts will clarify how our Game Matrix operates in practice.

We applied the previously defined design methodology in three phases. The first pilot event took place in the summer of 2022 and involved a summer camp where students in grades 4 to 12 were tasked with designing games for their grandparents. The second event was a design challenge given to undergraduate research assistants in summer 2023. The third occurred in winter 2024, where we presented the games as a class project for the course CompSci 1XD3. This initiative resulted in over twenty games, of which we tested a subset in our engagement evaluation experiment. We will present the results of our proposed methodology in Chapter 6. Documentation for some of these games is included in Appendix B.

5.3 Grounded Theory

Grounded Theory (GT) is a qualitative research method designed to create theory from empirical data. It was established in 1968 by Barney G. Glaser and Anselm L. Strauss [35]. In contrast to conventional research methods that start with a hypothesis or established theory, grounded theory employs an inductive approach, allowing the theory to develop directly from the data collected. This methodology is especially valuable for examining new or less-explored phenomena where current theories may fall short.

5.3.1 The Process of Grounded Theory

The process of grounded theory can be broken down into the following key steps:

1. **Data Collection**

   - **Sources:** Interviews, focus groups, observations, open-ended surveys, documents, media, and more.
   - **Theoretical Sampling:** Data collection is guided by emerging concepts. As categories emerge, researchers seek out additional data to explore these categories further.

2. **Open Coding**

   - Researchers analyze raw data (like interview transcripts) line-by-line.
   - Codes are assigned to small pieces of text that seem significant or interesting.
   - These codes can be **descriptive** (e.g., "anger") or conceptual (e.g., "emotional labor").

3. **Axial Coding**

   - In axial coding, researchers identify relationships between codes.
   - Similar codes are grouped into categories and subcategories.
   - Example: Codes like "time pressure" and "workload stress" may be grouped under a category like **"stressors at work"**.

4. **Selective Coding**

   - Researchers identify a core category that represents the main concept or process being studied.
   - All other categories are linked to this core concept.

Stage	Objective	Example
Open Coding	Identify initial concepts from raw data.	Codes like ”stress”, ”time pressure”.
Axial Coding	Group similar codes into categories.	Merge ”stress” and ”time pressure” into ”work-related stress”.
Selective Coding	Identify the core category that explains the main phenomenon.	”Coping with stress” could be the central concept.

Table 5.1: Sample Coding Process

- Data that is no longer relevant to the core category is set aside.

5. **Memo Writing**
    - Memos are notes that help track ideas, decisions, and reflections throughout the research process.
    - Memos can document why certain codes were combined or highlight potential new theoretical insights.

6. **Theoretical Saturation**
    - This occurs when new data no longer yields new insights or concepts.
    - When theoretical saturation is reached, data collection stops.

7. **Theory Development**
    - The final step is to create a grounded theory — an explanatory framework that links together the key concepts, categories, and relationships identified during the analysis.
    - This theory is not a set of “universal laws” but an explanatory framework specific to the context being studied.

5.4 Data Collection Procedure

To implement the grounded theory approach, the following detailed methodology was reviewed and approved by the McMaster Research Ethics Board (MREB) Application **#6124**.

1. **Online Form Completion:** Participants will initially complete an online demographic information survey along with a consent agreement for their involvement in the study. This survey, created using Microsoft Forms, is expected to take no more than 10 minutes to complete.

2. **Scheduling and Group Formation:** Participants will be organized into smaller groups of four to six individuals to facilitate engagement and ensure manageable interactions. The scheduling of the engagement evaluations will be based on participants' availability, and the chosen venue will be at the McMaster campus, equipped with computers and focus group facilities.

3. **Engagement Evaluation Day:** Upon arrival, the Student Investigator or a study team member will read the Letter of Information (LoI) to all participants. They will be reminded of their right to withdraw from the study at any point should they choose to do so. Following this, participants will be divided into their predetermined smaller groups for the session.

4. **Online Gaming Experience:** Each participant will engage in playing specially designed online games aimed at detecting symptoms of PD. Participants will be provided with individual computers in the laboratory setting for this task. During gameplay, a designated research assistant will be present to offer

technical support and will also monitor interactions. Additionally, the research assistant will record participants' voices using Microsoft Teams to be used later for coding. After the experiment, the transcript of the voice will be compared to the original audio file by the research assistant, and the audio file will be removed. The transcript will be used for coding.

5. **Post-Game Survey:** After completing the online games—an activity expected to last approximately 30 to 40 minutes, contingent on individual participants' proficiency with technology—participants will fill out a brief online survey regarding their gaming experience. This survey will also be conducted via Microsoft Forms and will take about 5 to 10 minutes to complete.

6. **Focus Group Session:** Following the survey, participants will engage in a focus group discussion lasting approximately one hour, where they will share their experiences and insights related to the gameplay. Notes will be taken by the research assistant and Student Investigator using Microsoft One Drive. The discussion will be recorded via Microsoft Teams for transcription and analysis. The audio recordings will be disposed of after the transcription process has been completed.

7. **Incentive for Participation:** As a token of appreciation for their involvement, participants will be invited to a lunch gathering featuring pizza, fostering a sense of community and celebrating their contributions to the research.

8. **Subsequent Contact for Follow-up:** If necessary, researchers may reach out to participants for follow-up sessions to investigate improvements or changes to the game mechanics. The same data collection procedures will apply for these

additional interactions to maintain consistency and integrity in the research process.

5.5 Conclusion

In this chapter, we described the methodology employed for conducting this research. Based on the established methodology, we collected data and performed our analysis, which took place on the 30th of November 2024. In the subsequent two chapters, we will present the findings derived from our analysis.

Chapter 6

Utulizing Design Thinking Methodology Results

In this chapter, we present the findings from an experiment by designers using the DT Methodology, including the **Game Matrix**. Although we have utilized this methodology at various events, we focus here on its effects on young designers during a specific event. In winter 2023, we introduced the games as part of a class project for the course CompSci 1XD3. We gathered student experiences with both the design methodology and TEASync, a framework designed for creating multiplayer games. Feedback was collected through surveys and focus groups. This chapter covers the insights gained from the focus groups, exploring student experiences from two angles: their engagement with the Game Matrix and its impact on the design process, as well as their perspectives on employing DT for developing human-centered games for older adults. The entire process of conducting the focus groups and surveys underwent review and approval by the McMaster Research Ethics Board (MREB) Application **#6868**.

6.1 Student Experiences with the Game Matrix

While many students found the matrix helpful, their experiences highlighted both the strengths and limitations of this approach.

Many students appreciated how the Game Matrix provided a structured starting point for their creative process. As one student explained, **"I thought it was helpful because it sort of forced us to have a starting point, right? We had to focus on something that specifically would do something about...Like it's sort of like was a good basis of showing us how ideas could fit into each of these categories and helped us think in terms of these symptoms and what are we want our games to really accomplish."** This focus on specific parameters helped students to approach game design in a more targeted manner. The matrix encouraged them to think about the relationship between game mechanics and their intended purpose, leading to more thoughtful design choices.

Furthermore, the game matrix was effective in prompting students to explore a wider range of ideas. As another student stated in the focus group that **"It helped us generate a lot of ideas," one student noted, "and it did kind of, some games were very different than others because some were more for certain symptoms and stuff, better for certain symptoms."** The structured nature of the matrix encouraged students to consider multiple possibilities, even though they might not have initially considered. Another student observed that, **"with this we were forced to finish the chart and then we ended up finding more good ideas later on when we were creating the chart. And so I thought that was helpful because there might have been ideas that we wouldn't have thought of if we just went with the first one we all kind of liked."** This indicates that the matrix encouraged a more thorough exploration of the design space. Another student mentioned, **"...with regular brainstorming, what I found in the past was that once you kind of get an idea that you like, you kind of stop and then you just start with that right away."**

While the game matrix had many positive impacts, students also noted some limitations. Some felt that the matrix constrained their creativity by requiring them to think within pre-defined categories. One student commented, **"...being confined to like the four categories and then four different like I guess symptoms made it like you have to like think within a smaller box versus just kind of come with any idea and and see how it could work."** This suggests that the imposed structure, while helpful in some ways, also had the potential to limit the scope of their ideation.

When comparing the game matrix to other idea generation methods like brainstorming, students found that it offered a more structured approach. One student noted, **"It's sort of like was a good basis of showing us how ideas could fit into each of these categories."** This highlights how the matrix gave students a concrete framework for thinking about their game designs. While some students appreciated the forced structure of the matrix, they also saw value in more free-form brainstorming. One student noted, **"At the same time, we also were able to like, come up with an idea on our own with just traditional brainstorming after the fact."** This demonstrates that the matrix was not seen as the only approach for generating good ideas, but rather as one tool among many. Another student saw the potential to reuse the method, saying, **"Maybe just like your interviews, that sort of framework as a way to help brainstorm ideas in**

the future. Like just lay down like a grid of possible prompts and random words, and maybe a little mechanics, and then force yourself to think of a game idea built around that." This shows that the matrix not only helped with this project, but students could also see how to apply it to other creative projects in the future.

6.2 Designing Games for Older Adults

Students had a variety of opinions about the challenges and benefits of designing games for a demographic outside of their own, specifically for older adults.

Students noted that designing games for a demographic outside of their own, forced them to engage with different playing styles and preferences. One student found it beneficial to **"design games for demographic completely outside of our own because it really sort of forced us to engage with like the differences and the different playing styles that different people have and also really engage like the variety of even within a demographic. How many people take different things out of the games and how game ideas that might make like this is actually something interesting we learnt."** This suggests that the project also highlighted the diversity of preferences even within the older adult demographic.

Students learned that games that made sense to them, such as open-ended games, required more explanation to the older adults, who were more familiar with puzzle-based games with clear goals. One student explained, **"It took a little bit of explaining to some people because in their minds, games are a lot more about just some sort of goal puzzle games for very popular because of**

that, because the whole goal is just solve the puzzle and and like open ended games require a little bit more explanation." The experience pushed students to consider their target group, which was not their peers. As one student said, **"It is this whole time helping you to just think about your target group, right, which normally you supposed to be your peers, but now it is a different age group."** The project encouraged students to think outside of their own preconceptions and tailor their designs to the needs of their target group. As one student put it, **"I think it is a helpful introduction to project design and also to the importance of thinking because like if it was just create a group for our demographic, then we could just use a lot of our own ideas ... a demographic completely [different] from our own kind of put the focus on a tailoring to them and sort of uh, making sure we kept up with the interviews"**. This also shows that students felt the experience was a helpful introduction to project design and the importance of considering different user experiences. The project helped students realize the importance of conducting interviews to understand user needs. As one student explained, **"It like forced us to sort of think outside our own preconceptions and put us in the mind."** One student noted that this experience is going to be very useful when working with clients in the future, especially on sensitive topics like PD, as interviewing skills have been developed through this project.

Some students found it difficult to understand the perspectives of older adults, especially those with limited experience with video games. One student noted, **"It's also like trying to explain like the concept of a video game to somebody who's never really played a video game before... So what we think is**

intuitive wouldn't be as intuitive to them." This highlights the challenge of bridging the generational gap in terms of gaming experience. Students had to grapple with how to communicate their ideas to the older adults during the DT process. They found that using paper prototypes was difficult, as it was hard for the interviewees to grasp what the actual game would be like. As one student put it, **"it's very hard to explain to people like this is an actual, soon to be an actual game and it is hard for them to read like just the paper to see what it looks like."**

The limitations of remote interviews, where students had to hold a camera up to a screen to demonstrate their game, further complicated the process. One student explained, **"...in the current implementation we would call via like some WhatsApp or something where we're kind of holding the camera up to the screen and having them tell us what to do and this was... kind of annoying to test and to get them to tell us. Ohh, click here"**. This highlights the practical difficulties of testing with a remote demographic. Students found it difficult to convey the core ideas of their games to individuals who couldn't directly interact with the programs. This is because, as one student noted, **"...there's always like a middleman, so that kind of makes it a bit difficult to really get like the core idea of what the game is towards them."**

6.3 Conclusion

In summary, the combination of the Game Matrix framework and the "grandfather game" design problem provided students with a comprehensive and enriching learning experience. In our past experience with similar populations of designers we were used to seeing a smaller number of repetitive ideas. Designers would latch onto the first reasonable idea they had. With the Game Matrix the number and variety of ideas was greater, although we cannot quantify the increase, due to ethics limitations. But the focus group participants were very clear that the Game Matrix facilitated idea generation and structured exploration of game design. Students faced with sixteen boxes will assume they should all be filled in. Focus group members even recognized when the Game Matrix was too constraining, but even then, completing the matrix gave them a solid base from which to jump to more creative ideas. The "grandfather game" design problem further deepened their understanding of design by emphasizing the need for empathy in human-centered design, because they could not reasonably substitute their own perceptions and points of view, because older adults were just too different. This fostered an appreciation for diverse perspectives, and highlighted the complexities of designing across generational divides. Together, these experiences equipped students with not only practical game design skills but also broader insights and adaptability that are valuable for future projects and professional growth.

Chapter 7

Qualitative Surveys Results

We have created and executed a range of games based on the design methodology outlined in Chapter 5. Afterward, we carried out qualitative evaluations to measure the effectiveness of our game design methodology.

A comprehensive survey was deployed to gauge participant engagement levels with the games, taking into account various demographic factors. Furthermore, focus group discussions were conducted to ascertain the specific factors and characteristics that enhance the engagement of older adults with these games, thereby facilitating their prolonged interaction and aiding the primary objective of data collection.

In the following sections, we present a detailed account of our methodology, commencing with a discussion of the conducted game evaluation session. Subsequently, we reveal the findings from our demographic survey, which provides foundational insights into participant expectations and baseline engagement levels. This will be followed by an analysis of the engagement survey results, enabling us to compare responses before and after the gaming experience.

The subsequent section is dedicated to the outcomes derived from our focus group discussions, which aimed to deepen our understanding of the older adults' perceptions and engagement with the proposed games that would provide us with the characteristics of games for older adults. Finally, we will conclude this chapter by synthesizing the combined findings from our research.

7.1 Evaluation Procedure

The evaluation of our methodology was conducted on November 30, 2024, at the McMaster Campus in PGCLL M21. A group of eight volunteers, all aged 50 and above, participated in the study, which lasted nearly two hours, beginning at 11:00 am. Initially, the participants were informed about the study through a Letter of Information (LoI) and signed the consent forms in accordance with MREB **#6124**. Subsequently, each participant completed a demographic survey.

After completing the survey, each volunteer was seated at a dedicated computer to engage with five selected games. A dedicated research assistant was present for each participant to address any questions or problems they experienced during playing. The research assistant was also responsible for recording the gameplay sessions for later analysis.

The final step before commencing the focus group was for participants to complete an engagement survey, in which they provided feedback about their experiences while playing the games. Eventually, all participants joined a focus group to discuss their collective experiences with the games, which lasted approximately 50 minutes and were fully recorded.

Upon conclusion of the evaluation, all demoghraphic and engagement survey results, along with the audio recordings, were utilized for further analysis for presenting the findings of this chapter. From the collected audio recordings, it was noted that the quality of the audio during gameplay was often inadequate for generating transcripts, or participants chose not to speak while playing the games. The following sections present our results based on the procedures outlined in this chapter.

7.2 Demographic Survey Results

The demographic survey aimed to capture participants' demographic profiles, technology usage, and digital habits to provide context for the subsequent evaluation procedures. This section presents a descriptive analysis of the responses, highlighting key trends and participant characteristics.

7.2.1 Demographic Profile

Regarding gender distribution, among the total participants, five identified as female and three as male. The participants' education levels show a diverse array of academic backgrounds. The largest segment, making up 37.5%, consists of three individuals holding a High School Diploma or GED. Close behind, 25% of participants, or two individuals, have a Master's Degree. The other education levels are evenly distributed, with 12.5% of participants—one individual each—possessing a 2-year College Degree, a 4-year College Degree, and a Doctoral Degree. This distribution showcases a variety of educational achievements within the group. Notably, 62.5% of the participants have at least some form of post-secondary education (2-year degree or higher). The employment status of the participants reflects a varied landscape of work engagement. A significant majority, 62.5%, are employed for wages, amounting to 5 individuals.

In contrast, a smaller portion of the group is self-employed, retired, or engaged as homemakers, each category representing 12.5% of the participants, with 1 individual in each of these statuses. This distribution illustrates a predominantly employed group while also highlighting the presence of individuals with diverse employment circumstances.

7.2.2 Technology Use and Digital Literacy

The feedback regarding smartphone usability among participants shows a largely positive sentiment. Half of the respondents, equating to 50%, find smartphones easy to operate, with a total of 4 individuals indicating this. Furthermore, 25% of participants, or 2 individuals, rate their experience as very easy. In total, 75% of participants categorized smartphone use as either "Easy" or "Very Easy," reflecting a substantial level of digital competence. Only 25% felt it was "Neither easy nor difficult," suggesting that while the majority are comfortable with smartphone technology, a small fraction may need additional support.

When it comes to using smartphones for health information, 50% of participants, or 4 individuals, do engage with this technology. In contrast, 25% (2 individuals) do not use smartphones, while another 25% (2 individuals) remain uncertain. This becomes even more intriguing when the question is rephrased. Half of the participants, also 50% (4 individuals), seek health-related information online, whereas the remaining 50% (4 individuals) do not.

Regarding recent health information searches, a significant majority of participants, 87.5% (7 individuals), have not searched for health information in the recent past. In comparison, only 12.5% (1 individual) reported having conducted a search during the same period.

7.2.3 Technology Adoption and Usage Patterns

All participants have internet access at home and regularly use video calls to connect with colleagues, friends, or family. The research on gaming habits reveals a balanced view of smartphone gaming among participants. Fifty percent (4 individuals) report using their smartphones for gaming, while the other fifty percent (4 individuals) do not. When looking at recent gaming activity, only 25% (2 individuals) stated they played a smartphone game yesterday, whereas a significant 75% (6 individuals) did not engage in gaming that day.

7.2.4 Discussion on the Demoghraphic Survery Results

While the sample size is small, the group appears diverse in education, employment, and engagement habits. The data also reveal some interesting information about Digital Literacy, Health-Seeking Behaviour, Educational and Employment and their relation with each other. Higher education levels show a moderate correlation with the perceived ease of smartphone use. This aligns with expectations, as individuals with more education often have greater familiarity with technology. Additionally, there is a positive correlation between higher education and the use of smartphones for accessing health information. People holding advanced degrees (Master's, Doctoral) are more inclined to utilize smartphones for this purpose. A similar trend is noted regarding the perceived ease of using technology, where individuals who report greater ease with smartphone use also tend to have higher education levels. There is a mild positive relationship between employment status and ease of smartphone use. People who are employed, particularly those in "Employment for Wages" roles, tend to report higher levels of ease in using smartphones. This might be due to frequent exposure to technology in work environments. Those who are "retired" or "homemakers" may not use smartphones as frequently, leading to reduced familiarity and lower ease-of-use scores.

7.3 Engagement Survey Results

The engamgnet survey was conducted to assess the participants' levels of engagement while interacting with the games. This survey employed qualitative methods, utilizing a series of Likert-scale questions with responses ranging from "Yes" to "No." In this section, we synthesize the fundamental insights extracted from the descriptive statistics and the response frequencies of participant feedback. The analysis is meticulously organized to furnish a comprehensive understanding of participants engagement and experiences throughout the gaming sessions.

The reported results reveal a significant level of participant engagement in the evalution. When asked the question, "I lose track of where I am," 100% of participants expressed some degree of agreement: 87.5% answered affirmatively with "Yes," while 12.5% responded "Sort of." This finding indicates an environment that effectively captures participants' attention. Notably, temporal distortion was also observed. In response to the statement "Time seems to stand still or stop," 50% of participants replied "Yes," 25% answered "Somewhat," and 25% chose "Neutral." Furthermore, 62.5% of participants indicated agreement with "Somewhat" or "Yes" in response to the statement "I lose track of time," which underscores the high level of involvement participants exhibited during the assigned activity.

Numerous inquiries were conducted to investigate participants' engagement with their external environment during play. For example, the assertion, "If someone talks to me, I don't hear," led to a response distribution in which 50.0% of participants responded with "Somewhat," while the remaining 50% selected "No" or "Sort of." However, In response to the statement, "I don't answer when someone talks," the results indicated that 12.5% answered "Yes," 50.0% responded "Somewhat," and 25.0% chose "No" or "Sort of." Overall, approximately 62.5% of participants demonstrated at least a moderate reduction in external responsiveness.

Emotional responses were predominantly classified as neutral to positive. In reaction to the assertion, "I feel scared," a total of 75.0% of participants either selected "No" or "Sort of," while only 25.0% demonstrated some degree of anxiety by selecting "Somewhat," indicating a lack of strong fear responses. Conversely, feelings associated with the statement "I feel spaced out" were markedly prevalent: 87.5% of participants responded with "Yes," and 12.5% chose "Sort Of." This trend suggests a cognitive shift towards a more absorbed and less critically self-aware state. With respect to the assertion "Playing seems automatic," 62.5% of participants replied with "No" or "sort of ,"" while an additional 25% opted for "Somewhat" or higher. This finding indicates that the majority of participants believe they maintain sufficient control over their actions while engaging in the games. These statistics substantiate the proposition that the games facilitated a "flow-like"" state for the participants.

With regard to ongoing engagement, 75.0% of participants indicated that they played for longer durations than initially intended, reporting at least a moderate level of agreement (classified as "Somewhat"" or higher), and all of the respondents expressed a sentiment of being unable to cease playing. These statistics imply that, while not all individuals felt a strong compulsion to engage, a significant portion encountered challenges in disengaging from the activity and demonstrated a willingness to persist.

In summary, the findings indicate a discernible pattern of profound immersion among participants. All participants (100%) reported a loss of awareness of their real-world surroundings, while a significant majority experienced temporal distortion (75%) and a heightened sense of cognitive "flow.". The emotional states observed were predominantly neutral. Furthermore, approximately half to two-thirds of the participants noted a decreased responsiveness to external communication and engaged in prolonged gameplay sessions. These observations suggest a substantial level of engagement with the games involved in the study.

7.4 Grounded Theory Result based on the Focus Group

This section presents the findings from a focus group that explored older adults' experiences with digital games. Using a Grounded Theory (GT) framework, the analysis highlighted key themes and categories that helped develop a theory regarding older adults' engagement with digital games. The analysis adhered to GT's systematic methodology. The first stage, open coding, involved breaking down the transcript into unique codes that represented participants' experiences. These codes were subsequently organized into broader categories through axial coding. In the final step, selective coding pinpointed a central category that formed the foundation of the emerging theory. Throughout this process, memo writing and comparative analysis were utilized to ensure the rigour of the theory.

7.4.1 Open Coding

The analysis began with open coding of the participants' responses. The focus group transcript was categorized based on whether the facilitator was addressing the questions, asking follow-up questions, or providing feedback to a participant's response, or if it involved a participant elaborating on a question or contributing to the discussion. Given the anonymous nature of the responses, open coding was conducted on each reply independently to extract as many codes as possible. After completing the open coding for each response, duplicate codes were removed to finalize this stage. The Appendix A presents the complete list of codes derived from the transcript. The first column lists the codes; the second provides examples from the transcript that justify the addition of each code.

Based on the codes generated above and the number of responses we have received, we started the second phase to categorize the codes into more general coding groups. Here we present the list of the axial codes, for each, we present the key idea behind the code followed by enough corroboration on why a specific code has been selected. Here is the list of codes and number of times they have been used in each of them used in our focus groups conversation:

ID	Code		Description
1	CodeSkills	1	About improvement of skills on playing the games. "My vision, hands, and overall skills improved"

ID	Code		Description
2	CodeContinue	1	Continue playing. “I wanted to continue playing”
3	CodeNostalgia	1	Nostalgic games. “Colouring game reminded me of childhood”
4	CodePhilosophy	1	Philosophical discussion on the game challenge
5	CodeEngaging	2	Engaged in playing games. “Very engaging”
6	CodeImproveMethod	3	Any improvement in the research method such as better planning.
7	CodeExcellent	4	Any positive feedback: “The game itself was excellent regarding time and time management”
8	CodeNotGamer	8	Mentioned not having previous gaming experience. “It was my first time. Maybe it felt a bit unfamiliar initially”
9	CodeImmersion	9	Involved in the experiment. Using words such as captivating and involved.
10	CodePosEmotion	9	Enjoyment in playing the games. Using words such as Enjoy playing games.
11	CodeImprove	9	Game suggestions for specific improvement in game mechanics.
12	CodeDiversity	9	Mentioned having different games with a variety of game play.

ID	Code		Description
13	CodeHealth	11	Understands the diagnostic objective of the games which attracted them to the focus group, more than expectations about the games.

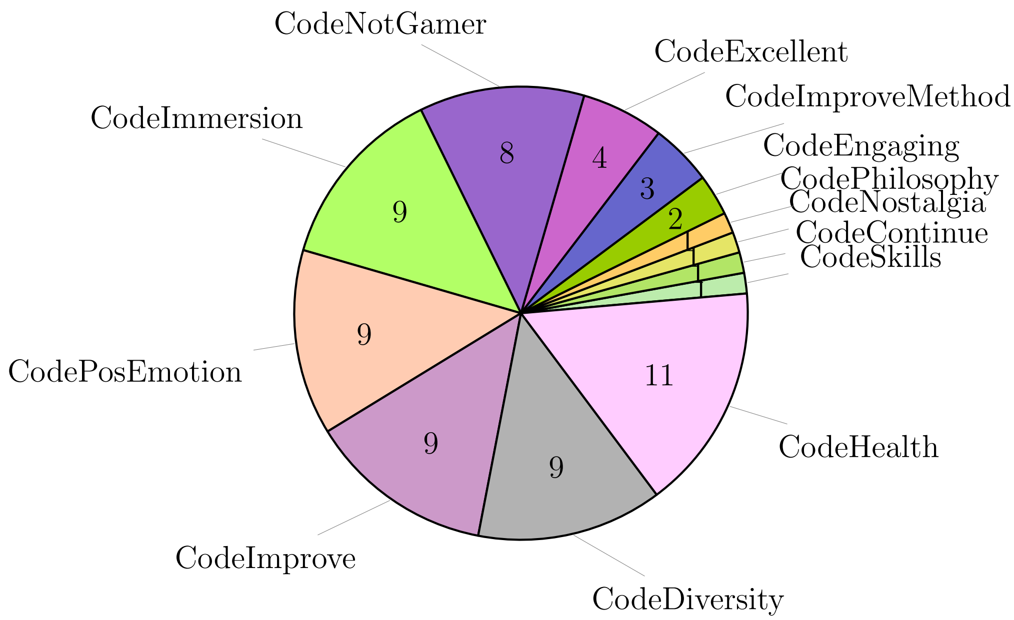

Figure 7.1: Pi chart of the frequency of the codes used in the focus group

Taking these codes into account, we can now begin to develop the primary categories and themes of the focus group.

Purpose, Utility, and Mission of the Games

Participants frequently reflected on the purpose behind the games, including their potential to improve cognitive abilities, reveal health-related insights (like PD symptoms), or serve as a mentally stimulating pastime.

- **Codes:** CodeHealth, CodeSkill, CodeDiversity

- **Conditions:** Clearly communicated objectives, perceived benefits such as memory improvement or reaction-time enhancement.
- **Actions/Interactions:** When players understood the game's potential benefits or underlying goals, they felt more motivated and invested. Ambiguity about the games' purpose led them to question their efforts.
- **Consequences:** Recognizing value and relevance (e.g., self-improvement, monitoring cognitive health) increased the willingness to begin and persist in playing and experimenting.

Engagement and Immersion

Participants often became deeply absorbed in the games, sometimes losing track of time and focusing solely on the task at hand.

- **Codes:** CodeImmersion, CodeExcellent:
- **Conditions:** Enjoyable mechanics, interesting gameplay elements, absence of anxiety-inducing features.
- **Actions/Interactions:** Players immerse themselves in the gameplay, pay less attention to external metrics (e.g., scoring), and often continue playing due to pleasure rather than external rewards.
- **Consequences:** Positive emotional experiences, satisfaction, and considering the game as a relaxing or engaging activity, sometimes even preferring it over other leisure options.

Emotional Responses: Positive and Negative

While many participants expressed positive emotions like enjoyment, satisfaction, and achievement, negative feelings such as frustration, anxiety, and mental exhaustion also appeared.

- **Codes:** CodePosEmotion, CodeExcellent, CodeNostalgia, CodeDiversity, CodeImprove, CodeImproveMethod
- **Conditions:** Emotional responses were influenced by how well the game matched player expectations, whether adequate feedback was provided, and the degree of challenge presented (Rabbit game for negative feedback, Card game or Camping game for positive). This also occurs when players are drawn to games due to the nostalgic feelings they evoke or the variety of activities available during gameplay (Playing card or camping games).
- **Actions/Interactions:** When challenges felt fair and understandable, participants felt pleasure and motivation (Camping and Card). When tasks were unclear, overly difficult, or lacked progress cues, frustration and exhaustion rose (Rabbit, Pizza displacement).
- **Consequences:** Positive emotions encouraged continued play and exploring more games; negative emotions led some participants to avoid certain tasks (e.g., the rabbit game, try to make ice-cream or burger instead of pizza) or question the game's design (Ask for improvement on the game mechanics or feedback mechanism).

Challenge, Difficulty, and Skill Development

Participants were drawn to challenges that tested memory, reaction speed, and problem-solving, as long as these challenges were not insurmountable.

- **Codes:** CodeSkill, CodeDiversity, CodeHealth
- **Conditions:** Balanced complexity, meaningful progression, presence of cognitive tasks that encourage players to improve.
- **Actions/Interactions:** Players attempted to learn patterns, refine strategies, and adapt to the tasks. They valued the sense of achievement that came from mastering a difficulty or improving their performance over time (Playing Card games, Solving Memory challenges, Mental challenges such as preparing the foods).
- **Consequences:** Appropriate challenge levels fostered personal growth, mental engagement, and satisfaction. Overly complex or poorly explained challenges, however, led to discouragement.

Game Design Features and Mechanics

The structural elements of the games—such as clarity of instructions, variety of tasks, feedback mechanisms, and complexity—heavily influenced user experience.

- **Codes:** CodeImprove, CodeImproveMethod
- **Conditions:** Accessible interfaces, intuitive controls, variation in tasks, clear progression, and meaningful feedback.

- **Actions/Interactions:** Players engaged more with games that felt fair and transparent, appreciated nuanced cognitive tasks, and responded positively to aesthetically pleasing elements. They were critical when a game lacked variation, was too simplistic, or failed to provide helpful cues (e.g., success alerts).
- **Consequences:** Positive design leads to enjoyment and continued engagement, while design shortcomings (such as confusing colour schemes or lack of clear success indicators) result in boredom or frustration.

Adaptation, Individual Differences, and Experience Background

Individual players' previous gaming experience, personal interests, physical or visual abilities, and risk-taking attitudes shaped their engagement and reactions.

- **Codes:** CodeNoGamer, CodeDiversity, CodeSkill, CodeHealth
- **Conditions:** Variation in age, familiarity with gaming, comfort with technology, and cognitive/physical capabilities.
- **Actions/Interactions:** Some participants adapted quickly and enjoyed experimentation, while others struggled with more complex tasks or certain interfaces.
- **Consequences:** Differences in background and ability influenced whether a participant found the games too simple, too complex, or just right. This led to diverse emotional outcomes and varying motivations to persist, improve, or disengage.

Cognitive and Physical Skill Interaction

Players valued games that integrated mental and physical elements, especially when these challenges felt attainable and meaningful (e.g., reaction speed and strategic thinking while playing burger game).

- **Codes:** CodeDiversity, CodeSkill, CodeHealth
- **Conditions:** Tasks requiring both cognitive engagement (memory, pattern recognition) and physical responses (timing, dexterity).
- **Actions/Interactions:** Participants tested their abilities, looked for ways to improve, and appreciated feeling mentally "exercised."
- **Consequences:** Success in these dual-challenge scenarios provided a sense of accomplishment and could foster ongoing interest, while overly demanding tasks without adequate support led to frustration.

7.4.2 Proposed Core Categories

In the focus group, two predominant themes emerged. The primary core category is the mission, while the secondary is the supportive design. Participants emphasized the importance of engaging with our games due to the mission and objective behind them, rather than the design itself. This is evident from the frequency of references to CodeHealth. It suggests that regardless of the game's design quality, participants are inclined to try the games at least once. However, it is the supportive design that encourages continued gameplay. Thus, we identify two main core categories.

- Achieving Motivation Based on the Purpose and Mission of the Games.

- Achieving Engagement Through Balanced Challenge and Supportive Design.

Here is how these two core categories aligned with our focus group.

1. Identification with Mission:
    - When participants recognize the reasons for their play and its benefits—mentally, physically, and emotionally—for themselves and for others, including its potential use in diagnosing, treating, or monitoring symptoms, they remain more engaged and find the experience more meaningful. This is totally aligned with first proposed category.
2. Game Design Features and Mechanics:
    - When the design aligns with players' capabilities and provides consistent, helpful feedback, participants feel supported and motivated. This is aligned with the second proposed category where it emphsized supportive design. High engagement and immersion occur when the game's challenges feel manageable, its objectives are understandable, and its mechanics encourage focused attention. Immersion thus becomes a natural outcome of the balanced and supportive environment described by the core category.
3. Emotional Responses (Positive and Negative):
    - Positive emotions emerge when participants grasp the goal, find the challenge suitable, and receive constructive feedback—elements that define meaningful engagement. Conversely, negative emotions arise when the game does not clarify its objectives, presents challenges that are either too difficult or too easy, or provides insufficient encouraging feedback. This

aligns with the core categories, as using a product that positively influences participants' quality of life fosters positive emotions. In contrast, a lack of supportive design can lead to negative emotions, ultimately causing players to abandon the games.

4. Challenge, Difficulty, and Skill Development:

    - The idea of a "balanced challenge" is fundamental to the second core category. Players excel when faced with difficulties that challenge their skills without overwhelming them. To foster meaningful engagement, it is essential to provide tasks that enhance skill development while avoiding unnecessary stress or confusion. This is a crucial yet sensitive issue, as the concept of balance varies from one player to another. Differences in skill levels among participants can arise from their experience with digital games and their physical abilities in gameplay. A carefully tailored, balanced challenge would eventually help participants find their own pathways to enjoyment and growth within the same gaming environment.

We can now create our theoretical storyline to define our grounded theory.

7.4.3 Proposed Grounded Theory

The meaningful involvement of older adults in our games hinges on two key factors. First is the mission behind the games, which serves as a major motivation for them to engage. Second is the supportive design that encourages prolonged use. Players approach gaming experiences with different levels of familiarity, cognitive abilities, and physical skills. However, their primary motivation to try the games stems from knowing that these games might assist in monitoring PD symptoms more easily in the future, providing sufficient incentive to attempt the games at least once. The games offer tasks that can either foster immersion and enjoyment or lead to frustration and anxiety, largely depending on how clearly they communicate their objectives, adjust difficulty levels, and deliver helpful feedback. For instance, some participants expressed frustration and anxiety while playing the rabbit game or attempting to prepare a pizza order, whereas most enjoyed games involving cards, camping, and preparing burgers and ice cream due to the familiarity and balance of challenges, along with the supportive design integrated into the game mechanics.

When game design is responsive and well-balanced—providing an optimal level of challenge, clear guidance, and a meaningful objective—players become fully engaged, losing track of time while deriving enjoyment, knowledge, and satisfaction from the experience. In this ideal scenario, emotional reactions are positive, skills develop progressively, and participants feel acknowledged and valued as individuals with diverse backgrounds and needs.

In contrast, when a game lacks clarity, adjustable difficulty, or significant feedback, players find it hard to grasp the expectations, feel overwhelmed by poorly articulated mechanics, and ultimately experience frustration or disconnection. Without a balanced environment that addresses their doubts and skill levels, genuine engagement fades away.

7.4.4 Summary

Thus, the proposed theory highlights a dynamic interplay: Meaningful engagement in digital games created to detect or monitor health symptoms in older adults stems from the games' mission and objectives, along with supportive design. This includes a balanced challenge, a clearly communicated purpose, accessible and intuitive design choices, and responsive feedback. These components collectively promote a sense of mastery, well-being, and mental stimulation, allowing older players to not only enjoy the experience but also recognize how it can support their personal goals, whether cognitive, social, or recreational.

Chapter 8

Conclusion

In this chapter, we summarize the key findings and contributions of this thesis, reflecting on the research undertaken and its implications for the field.

8.1 Research Motivation

The main goal of this research was to enhance user engagement with applications specifically created for the collection of medical data. To achieve this, we proposed using games as a substitute for traditional apps, as games tend to motivate users more effectively.

This brings us to our secondary objective: to inspire young designers to create games tailored for older adults. We suggested adapting the DT methodology, utilizing a Game Matrix. This adaptation aims to motivate young designers to conceptualize applications for a demographic that is different from themselves, thereby challenging them to develop empathy.

Furthermore, the Game Matrix is designed to maximize the rate of idea generation during the ideation phase, and prevent teams from prematurely settling on an idea. Students also reported that ideas in the matrix belonged to the team, which encouraged everyone to contribute. By integrating this methodology, we hoped to foster creativity and innovation in designing engaging, effective games for older adults.

8.2 Research Key Findings

Here is the key findings of this research:

1. The DT methodology utilizes the Game Matrix for ideation, proving effective in designing engaging games for older adults while consistently incorporating a variety of symptom measurements. Additionally, it successfully motivates young designers to tackle design tasks outside their experience.

2. The game prototypes developed using the DT methodology outlined in this thesis have effectively engaged research volunteers. An unexpected finding from this research shows that the primary motivation for participants to begin using our games is the underlying purpose, rather than the game design itself. Design elements take a secondary role in maintaining their engagement and encouraging prolonged use of the app. Nonetheless, volunteers were suprised at how well the games catered to their age group and range of abilities.

3. According to the proposed grounded theory, aside from the intent behind the games, the key factors that enhance engagement are balanced challenges and supportive design. Definitions for these two terms can be found in Chapter 7.

8.3 Contributions to the Field

This thesis advances human-centered design by presenting Game Matrix, an alternative to morphological charts that enhances idea generation. Additionally, it highlights engaging elements for games targeting older adults in the context of medical data collection by balancing purpose and design elements. Furthermore, it underscores balance challenge and supportive design as two key factors that boost engagement.

8.4 Threats to Validity

The validity of our findings is limited by constraints on our ability to sample our two populations. The undergraduate students were all from the Computer Science program at McMaster University, and data was collected on an opt-in basis. Other young designers might react differently, and produce games with different levels of success. Furthermore, our sample of older adults were all from Middle Eastern and Asian backgrounds. This limitation emerged due to difficulties faced in recruiting an adequate number of volunteers for the experiment. Nonetheless, we maintained our criteria, ensuring that all participants were aged 50 and over, and demonstrated an adequate level of technological competency. Since the games were not specifically designed for this demographic, there is no reason to suppose that the games are uniquely engaging to this group, but there is a risk that other demographics would react differently.

8.5 Future Work

The experiences we gained from the research volunteer recruitment process, along with the process of applying the design methodology and the insights gathered from the focus group, suggest the following future directions:

Co-Design Our experience utilizing DT in a human-centered design framework, particularly focusing on older adults as the target demographic, along with the feedback received from our volunteers, indicates that exploring this methodology through a co-design approach could lead to improved game mechanics. This improvement is primarily because older adults bring valuable first-hand experience to the design process, contributing insights and perspectives that can enhance the overall effectiveness and enjoyment of the game.

Segmentation The World Health Organization (WHO) has recently updated its classifications for age, resulting in the segmentation of individuals aged 57 to 90 into four distinct age groups. This consideration has not been taken into account during our design process. It is essential to explore how these newly defined age categories might influence the preferences of older adults when it comes to selecting games. Understanding these dynamics could significantly impact the design approach and the overall user experience.

Sensors A limitation of the current research is the restriction of implementation language to Elm using the GraphicSVG library for interactivity, which does not support all of the data sources on a smartphone (i.e., camera, gyroscope). Games were also designed for a large screen. Following the success of our prototypes, we can shift our attention to creating native smartphone games that will enhance access to additional sensors, including the accelerometer and gyroscope. This approach will not only facilitate the collection of data on various other PD symptoms but also enable us to investigate diverse game mechanics designed to address both the symptoms and the sensors at our disposal.

Adjustment To further elucidate the balance challenge, it is essential to tailor it according to the skill level of older adults. In summary, the difficulty of the game should progressively adapt if the skill level of the older adult does not meet anticipated standards. Achieving this may require implementing a machine learning-based approach, which necessitates further exploration and research.

Generalization This research focuses on Parkinson's Disease, the specific neurodegenerative condition targeted in our game design. The study's findings and the suggested design approach highlight the considerable potential of smartphone games and gamification techniques to aid in the detection and monitoring of various other neurodegenerative disorders.

8.6 Final Thoughts

In conclusion, this research highlights the significance of human-centered design in developing games targeting older adults for collecting medical data. It lays the groundwork for exploring similar strategies for disease detection and monitoring in light of situations like the COVID-19 pandemic. With life expectancy on the rise and future generations becoming more tech-savvy, adopting this approach could be a more cost-effective approach to screening older adults for the expected increase in neurodegenerative disease.

Appendix A

List of the Open Codes

Here is the list of the preliminary open codes for the focus group.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
1	**Engaging**	I feel it was very engaging.
2	**Good feeling**	I have a good feeling about playing this game.
3	**Captivating**	It was so captivating.
4	**Time perception**	I didn't notice the time and felt good about it.
5	**Positive emotional experience**	Using words like "good" and "feel good"
6	**Immersion**	The focus on time being unnoticed
7	**Involved**	I felt very involved in the game.
8	**Enjoyment**	I enjoyed it so much.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
9	**Satisfaction**	Wanted to continue playing.
10	**Positive Evaluation**	The games were very good
11	**Frustration**	The rabbit part was quite frustrating.
12	**Problem with the game mechanic**	"The pizzas didn't stay in place," or "Once placed, they should disappear."
13	**Multi-tasking challenge**	Managing multiple orders simultaneously... was a bit challenging.
14	**Positive assessment of characters**	The rabbit was fine; it was quite sly.
15	**Unfamiliar with games and social media**	Usually, I am not into games or social media
16	**Understanding the goal**	When I asked others about this and understood the kind of outcome you were aiming for
17	**Positive reaction to the aim of the game**	I was pleased... I hope you succeed and achieve your goal.
18	**Personal testing of abilities**	It was a way to test my abilities and understand my health and reaction speed.
19	**First-time experience and unfamiliarity**	It was my frist time. I felt a bit unfamiliar
20	**Expectation of improvement**	I think I'll get better with more attempts.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
21	**Improvement of skills**	The more I played, the faster and more accurate my response became.
22	**Mental improvement**	I could do things and improve mentally
23	**Prior gaming experience**	Since I've played games extensively before.
24	**Praise for design**	The choice of colours was very good, and the characters were well-designed
25	**Technical issue with the camera in the game**	Perhaps the camera used to locate the birds wasn't optimal.
26	**Positive feedback on a specific game**	The burger game was great, and the card games were fantastic
27	**Reaction speed mismatch**	My brain's reaction speed didn't match my hand movements
28	**Lack of progression or feedback system**	Games usually encourage players to advance... but that aspect was missing or very minimal
29	**Praise for camping game**	The camping game was great
30	**Age Categorization**	Ages between 57 to 90 are now divided into separate age groups.
31	**Enjoyment about the games**	The last two games were particularly enjoyable.
32	**Missing content**	We didn't visit the city.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
33	**Feedback on game progression**	The games could have been more challenging.
34	**Positive but not perfect experience**	It wasn't bad, but it could have been more challenging.
35	**Overall positive experience**	Overall, it was very interesting.
36	**Appealing to experienced players**	The games also appealing to experienced players
37	**Game diversity**	The games had enough diversity to engage both groups
38	**Progression in the rabbit game**	The rabbit game become progressively harder, it had various levels.
39	**Lack of progression in some other games**	Some of the other games stayed on the same level without progression.
40	**Nostalgic reference to the colouring game**	The colouring game reminded me of childhood colouring books.
41	**Accessibility for the basic skills levels**	For someone at a basic skill level, it was good.
42	**Inclusive game design**	Even someone unfamiliar with computers could still participate
43	**Frustration with speed in the rabbit game**	As it speedup, I couldn't keep up

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
45	**Mental engagement**	The other games were great. They challenged the mind and encouraged thoughtful engagement.
46	**Absence of anxiety**	I didn't experience feat or anxiety while playing
47	**Distraction from preoccupation**	I didn't even notice the passage of time. These games can help distract the mind when someone is preoccupied with other things.
48	**Lack of experience with computer games**	I hadn't played computer or laptop games for about five or six years
50	**Enjoyment of specific games**	I really liked the rabbit, burger, and pizza game
51	**Immersive experience**	I couldn't tell if I was alone or surrounded by others – Time passed quickly, and I felt happy.
52	**Prioritizing the game over other tasks**	It was so enjoyable that even if my child asks me to cook food, I'll say "Let me finish my game first!!"
53	**Interest in playing the games on mobile device**	If it's for phones, I'll play

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
54	**Consideration of buying new equipment for playing games**	I might even buy a laptop just to play these games.
55	**Playing during free time**	Whenever I have free time... instead of watching TV, I'd play these games.
56	**Enjoyment of card game**	I loved the rabbit and the card game too.
57	**Wishing for more playtime**	I wish I could play more, but time is up.
58	**Assumption of purpose**	I assumed you had designed these games with a specific purpose in mind
59	**Acknowledgement of limitations**	Your games couldn't compete with something like COD in terms of animation and diversity.
60	**Sufficiency of purpose**	The games were sufficient for their purpose.
61	**Adaptation to conditions**	I adjusted to the conditions
62	**Enjoyment based on context**	I enjoyed them accordingly
63	**Simplicity and clarity**	The was nothing overly complex, and everything made sense in the given context.
64	**Acceptance of the experience**	Take it as it is

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
65	**Concern about the challenge**	I thought the games might be very challenging
66	**Age-related worry**	Especially given my age.
67	**Concern about game design**	The modern design
68	**Worry about keeping up**	I was worried I wouldn't be able to keep up.
69	**Positive outcome**	But it turned out to be fine.
70	**Concern about difficulty**	I thought the games might be very difficult
72	**Relief upon finding the games manageable**	I was glad to find they were manageable
73	**Games at an understandable level**	At a level, I could understand
74	**Expectation more action games**	I expected there to be shooting or war games.
75	**Interested in the absence of emotional manipulation**	The games weren't designed to manipulate emotions.
76	**The calming effect of the games**	I found games claiming.
77	**Confidence in accessibility**	I was sure the games chosen were accessible to people who were tech-savvy.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
78	**Willing to try new things**	I was also ready to tackle any kind of game present to me.
79	**Positive evaluation of simplicity**	The game chosen was very good — simple and stress-free.
80	**Initial anxiety and stress**	I have some anxiety and stress, wondering if I could mange them.
81	**Enjoyment after anxiety**	When I realized the games were enjoyable, I had a lot of fun.
82	**Time spent on figuring out the gameplay**	I felt I had to spend too much time figuring out how to make the pizza correctly
83	**Preference for easier games**	I switched to the burger game, I found easier to play
84	**Engagement with memory-based games**	The games that required me to use my memory like card games.
85	**The mental challenge from memory games**	They challenged me mentally.
86	**Enjoyment with the bird-colouring game**	The bird-colouring game was enjoyable as well.
87	**Challenge on recalling colours**	I had to pause occasionally to recall the colours

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
88	**Disinterest in the pizza game**	Only the pizza game. It didn't appeal to me much.
89	**Enjoyment of challenging games**	I enjoyed the ones that challenged me.
90	**Engagement with pattern and colour recognition**	Like recognizing patterns and colours.
91	**Enjoyment of figuring out the games**	I found it enjoyable to figure out how to play games
92	**Excitement from challenge**	That challenge was exciting for me.
93	**Curiosity about the detection mechanism**	What intrigued me was figuring out which of these games might be detecting my movements.
94	**Bored with colour design**	The colour design was fine, but it felt quite boring
95	**Questioning the games engagement level**	Would the game's design and engagement level be sufficient to draw them in, or would they lose interest?" shows doubt about the game's ability to sustain interest, particularly for older adults or those at risk
96	**Disparity in game levels**	But the games are not on the same level.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
97	**Desire for beneficial, engaging games**	I'm looking for how a game can engage me, what benefits it might have for me, or how it can keep me active
98	**Focus on mental stimulation**	Does it improve creativity, strengthen my memory, or stimulate my reaction speed?
99	**Enjoyment of dual challenge**	The part where the game challenged mental speed along with my physical response.
100	**Desire to improvement**	Can I manage it better this time?
101	**Seeking validation from games**	In my way get a good job from the game
102	**Reflection on Failure and improvement**	If I couldn't manage to succeed, I'd start thinking about how I could do better next time.
103	**Imagining new scenarios**	I even imagined that a rabbit might come from the other side
104	**Seeking pattern to improve performance**	I was looking for patterns, trying to figure out which one would be closer to the right one.
105	**Desire to keep playing despite challenges**	I would have kept going, though

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
106	**Limited strategic variation**	The tasks didn't allow for much strategic variation
107	**Frustration with limited planning opportunities**	Its increasing speed left little room for planning or experimentation
108	**Lack of repetition in the experience**	We didn't repeat any game
109	**Looking for a pattern.**	I, too, was naturally looking for a pattern.
110	**Inability to find a pattern:**	But I couldn't find one, even with the rabbit
111	**Frustration with the game:**	It was really impossible to work with.
112	**Feeling overwhelmed:**	It was just too much" highlights the participant's sense of being overwhelmed by the game, particularly due to the lack of pattern recognition and the challenge of the gameplay.
113	**Lack of variation in the colouring game**	The colouring game could have benefited from having more variation.
114	**Simplicity and lack of challenge**	It becomes a bit straightforward. It's not like you're really being challenged.
115	**Lack of engagement with colouring game**	If you made light blue into dark blue, it didn't feel as engaging.

Table A.1: The list of all preliminary open codes for the grounded theory

ID	Open Code	Example
116	**Contextual understanding of colour differences**	Forgetting the context makes sense in the case of distinguishing between a colour-blind person and someone without colour blindness.
117	**Impact of game rules on performance**	Especially when the game rules are unknown

Appendix B

Game Design Documents

B.1 Whac-A-Mole in the farm

Grandmother has moles on her farm that trouble her. She requested us to catch as many moles as possible.

Figure B.1: Whac-A-Mole Game Screen Shots

B.1.1 Gameplay Mechanics

- The game is a single-player game.

- The player will be using the mouse to play the game.
- The objective is to collect as many moles as it is possible.
- The player should click the moles on time in the game. The game will get faster gradually, making catching the moles harder and harder.
- The game will stop after a specific number of moles are collected or the timer finishes and the player is not able to collect enough moles.

B.1.2 Story and Setting

- The motivation for the user is to play a classic Whac-A-Mole game in a new design.
- The location of the game is a farm.
- We have three main characters. The grandmother, the Moles and the cow in the background.

Level Design

The game consists of a single level in which the speed of the moles gradually increases. As the game progresses, it becomes increasingly difficult to catch the moles.

B.2 Rabbit-And-the-Carrot

The farmer owns a carrot field and needs the player's help to protect his carrots. The rabbit constantly targets the darker carrots. The player's task is to click on the carrot before the rabbit reaches it to save it.

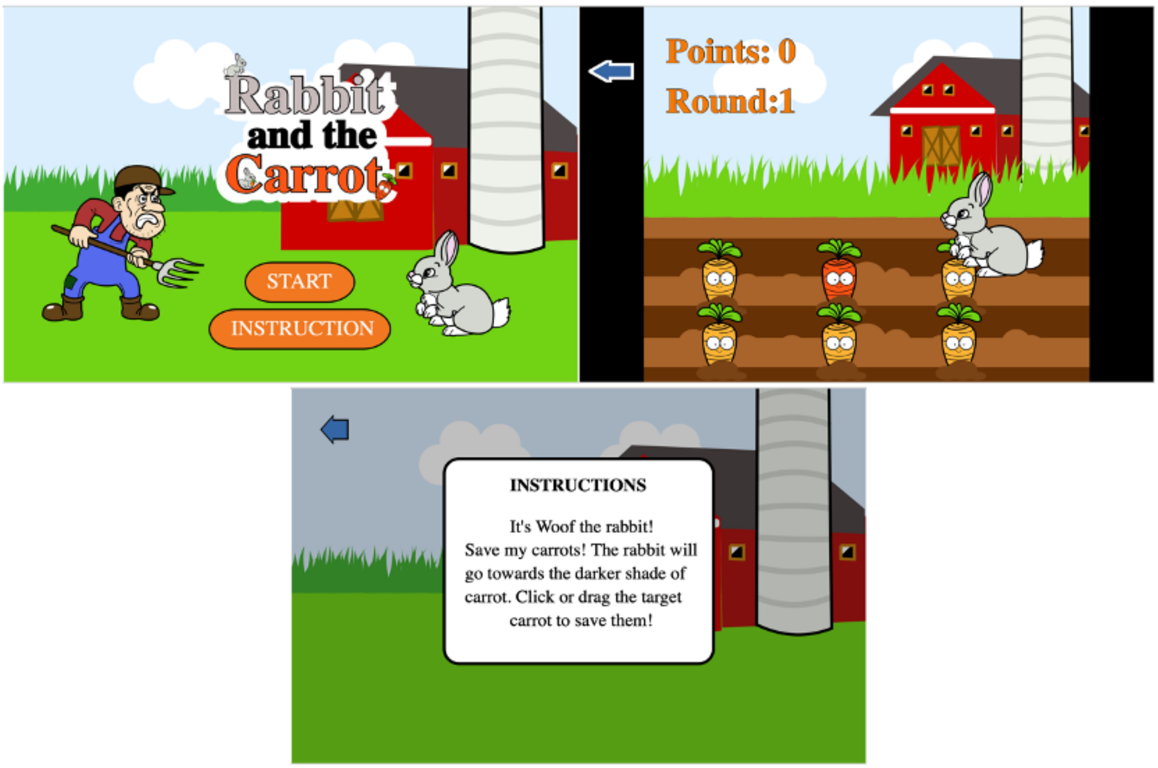

Figure B.2: Rabbit-And-the-Carrot Game Screen Shots

B.2.1 Gameplay Mechanics

- The game is a single-player game.
- The player will be using the mouse to play the game.
- The objective is to save as many carrots as it is possible.

- The player should click the darker carrot before the rabbit. The rabbit's movement will get faster, which makes saving the carrots harder each time.
- The game will stop eventually when the rabbit or the player catches all of the carrots survives a specific number of rounds.

B.2.2 Story and Setting

- The motivation for the user is to play is to play a farming game in with a story familiar to the older adults.
- The location of the game is a farm.
- We have three main characters. The farmer, the rabbit and the carrots.

Level Design

The game consists of three rounds. The speed of the rabbit will increase gradually while the player moves from one round to the other.

B.3 Apple Catcher

The restaurant cook requires apples to bake a cake. The players are tasked with catching as many apples as possible.

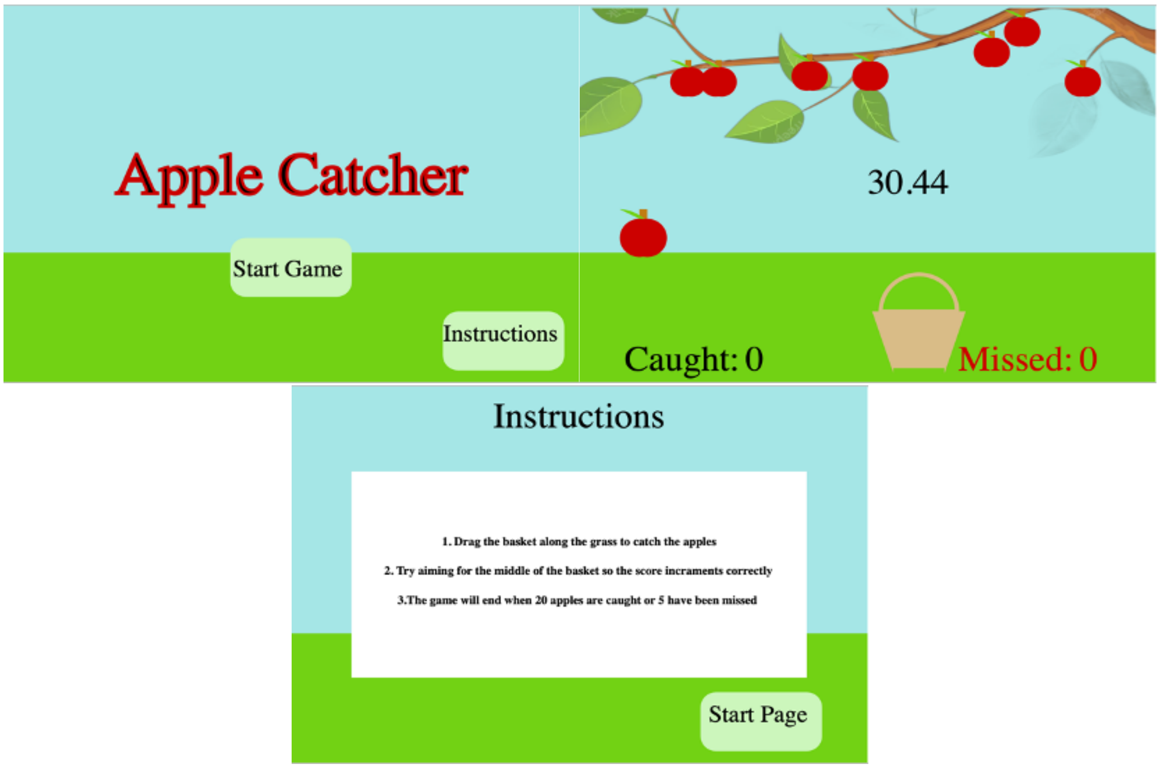

Figure B.3: Apple Catcher Game Screen Shots

B.3.1 Gameplay Mechanics

- The game is a single-player game.
- The player will be using the mouse to play the game.
- The objective is to collect as many apples as it is possible.

- The player should move the basket under the apples to catch them. The game will get faster gradually, making catching the apples harder and harder.
- The game will stop after a specific number of apples are collected or the player misses 5 apples.

B.3.2 Story and Setting

- The user is motivated to enjoy a classic Apple Catcher game, reliving the nostalgia of collecting fruits beneath the trees.
- The location of the game is a garden.
- We do not have any visible characters here.

Level Design

The game consists of a single level in which the speed of the apples gradually increases. As the game progresses, it becomes increasingly difficult to catch the apples after a point.

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