Assessing Sleepiness Through PVT Using Gamification As Intrinsic Motivation

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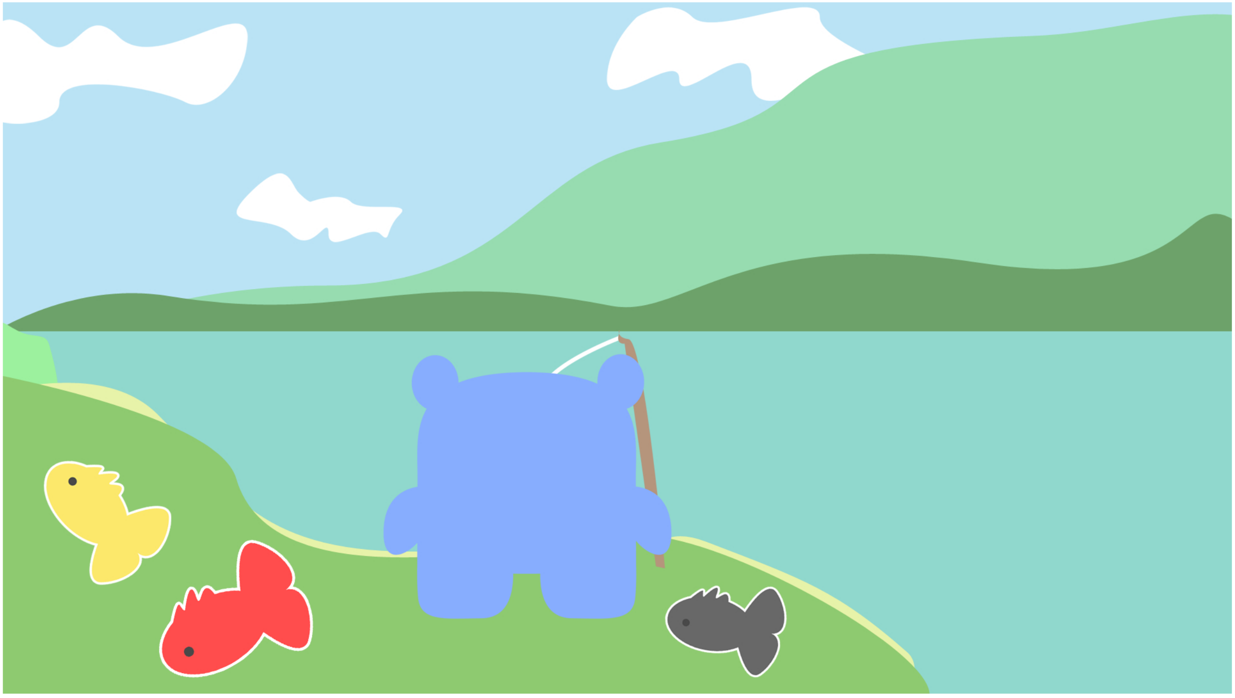

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Title:

Assessing Sleepiness Through PVT Using Gamification As Intrinsic Motivation.

Description:

An application is implemented to assess sleepiness through psychomotoric reaction-time using gamification as intrinsic motivation.

Theme:

Gamification And Sleepiness Applications.

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Participants:

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Abstract:

This project describes the development of an ubiquitous application for assessing sleepiness through psychomotoric reaction time. The application integrates gamification elements for maintaining users' intrinsic motivation towards the application. This is important because the psychomototoric reaction time test is often perceived as impractical both in form and design outside of laboratoy settings. Thus, the report layout consists of a literature review of sleep deprivation and its implications, followed by a literature review of game design and what constitute to the definition of gamification. The application is then designed and implemented in two versions, one version with gamification elements and another version without. The two versions are tested and evaluated on two different usergroups, where the findings are discussed along with the implications and limitations. Lastly, a conclusion is drawn with possible future work iterations in mind.

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Preface

This report is written as part of a 10th semester project at the Department of Architecture, Design and Media Technology. The project is executed by group mta141036 at the Medialogy study. The main theme of the project is: *Gamification And Sleepiness Applications*. The purpose of the project is to learn about the phenomena that is gamification and the impacts it has on users' intrinsic motivation for using a psychomotoric reaction time application.

The report consists of seven main chapters; Introduction, State of the Art, Application Design, Implementation, Gamification Test, Test Evaluation, and Conclusion.

Throughout the report there are references to the bibliography at the end of the report. References for the bibliography will either be before or after period. If it is before period, the reference only applies to the sentence. If it is after the period it applies to the paragraph. The references are written as the last name of the author as well as the year of publishing, for example [Nintendo, 2014] for Nintendo: *Super Mario World*.

There are references to appendices in the end of this report, as well as content stored on the enclosed DVD.

Parallel to the project, a video presenting the project has been produced. The 'AV-production' can be found on the enclosed DVD in the 'Video' folder.

Lastly, a demo of the game, along with the source code, can also be found on the DVD.

Acknowledgements

I would like to express my very great appreciation to Assistant Professor Hendrik O. Knoche and Research Assistant Lars Knudsen, my research supervisors, for their valuable and constructive suggestions and useful critiques during the planning and development of this research work. The willingness to give their time so generously has been very much appreciated.

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Chapter 1

Introduction

This project is concerned with users' intrinsic motivation for using applications such as the psychomotor vigilance test, for assessing their sleepiness state. Because sleep deprivation is a common practice in many occupations that demand 24 hours operations, such as nursing, mining, trucking, and aviation. Tragically, sleep deprivation has also been involved in many serious catastrophic incidents and accidents. Examples of recent history diasters is the 1979 nuclear accident at Three Mile Island, where shiftworkers did not notice the lost of cooleant between 4 and 6 a.m., which resulted in overheating the reactor's core. The 1986 nuclear meltdown at Chernobyl, where the engineers had been working for 13 hours or more, and as a result missed the warning signals on their control panels. The Challenger space shuttle explosion in 1988, in which certain managers involved in the launch had only slept three hours for three consecutive nights prior to the catastrophic incident. [Short & Banks, 2014; Mitler *et al.*, 1988]

The psychomotor vigilance test is a simple method, in which the user must respond to an active visual stimulus in a timely manner. The method is sensitive towards the ability to sustain attentive over a duration while doing a trivial repetitive task, which can be useful for indication and evaluation of one's sleepiness state. However, traditional equipment for performing such sessions commonly require a laboratory setting and frequent testing sessions with a set amount of time. This means the method is often perceived as a tedious task and impractical outside of laboratory settings, thus is not considered as a part of the daily routine for many people.

This project proposes a possible solution for making the psychomotor vigilance test more accessible and possibly more interesting as well, in the form of an ubiquitous application with gamification as the persuasive technology. Gamification is an increasingly phenomenon and still relatively new in the field of research and is most commonly found in marketing applications. The phenomenon borrows many aspects from play and game design and is used to integrate such features into non-gaming applications. The report presents the design for an application that is compatible for both personal computers and handheld devices such as smartphones and tablets, and with gamification as the chosen main drive for users' intrinsic motivation, the application aims to shift the focus towards the element of play rather than the up-front intended task.

The report layout consists of a literature review of sleep deprivation and its implications, followed by a literature review of game design and what constitute to the definition of gamification. Next, an application design chapter describes the design process, followed by an implementation chapter for the implemented application at hand. The report then proceeds to describe the test methodology and planned experiment. Finally, the findings are discussed along with the implications and limitations, and lastly a conclusion is drawn with possible future work iterations in mind.

1.1 Problem Statement

How does gamification affect users' intrinsic motivation of using PVT to assess their sleepiness?

Chapter 2

State of the Art

Through literature review, this chapter is seperated into two parts, where the first part reviews sleep deprivation and its implications along with a possible method for testing, namely the psychomotor vigilance test. In addition, the section also examine possible solutions for making the method more accessible and encouraging for users than its current state. This idea goes particularly well as technology becomes more accessible for everyone, thus a possible solution would be to bring the test method to the digital media, namely ubiquitous computing. The second section reviews possible solutions for how the digital application can be implemented with interesting and appealing features, resembling features from play and games, to shift the focus away from 'doing a tedious task' and thus may give users incentives to self-report their sleepiness through the digital application.

2.1 Sleep and Sleepiness

This section firstly review the cognitive and neurobehavioral implications of sleep deprivation from various research, with special focus on sustained attention. This is followed by a description of the psychomotor vigilance test along with a proposed standardized framework from previous studies. Thus, the proposed framework functions as the guidelines for this project's implementation of the digital application of the psychomotor vigilance test. Lastly, a literature review of current digital sleepiness applications, in addition to which method popular health applications use for bringing in new users and successfully maintain their users motivated in using the application.

2.1.1 Cognitive and neurobehavioral implications of sleep deprivation

Sleep deprivation is caused by the absence of sleep and may affect fatigue, daytime sleepiness, clumsiness and weight loss or weight gain, in addition to adversely affecting the brain and cognitive function. Sleep deprivation and several aspects of impairments have been investigated in previous studies and a link between sleepiness and accidents has already been well documented [Itoi *et al.*, 1993], as there are several of methods to measure sleepiness [Banks & Dinges, 2007; Short & Banks, 2014]. Ranging from self-report such as, *Epworth sleepiness scale* (ESS) to measurements such as *electroencephalography* markers (EEG) measuring latency to slow wave sleep (SWS), or the *multiple sleep latency test* (MSLT) and the *maintenance of wakefulness test* (MWT) [Short & Banks, 2014]. Using EEG to monitor brain activity, the MSLT measures the time taken to fall asleep in a sleep conducive environment, while the MWT measures the sleep latency under conditions where a subject tries to resist falling asleep. Studies have shown that both MSLT and MWT values decline during sleep deprivation, indicating that subjects fall asleep much more quickly when trying to sleep, and they also fall asleep faster even when they are attempting to stay awake [Short & Banks, 2014].

Even after one night without sleep, the reaction time slows and the ability to sustain attentive and vigilant is greatly reduced. A commonly used task for measuring vigilant attention and sleep loss is using the *psychomotor vigilance test* (PVT), recording the reaction time for responding to a given visual stimuli [Short & Banks, 2014]. Doran and colleagues [Doran *et al.*, 2001] found that after 18 hours without sleep, PVT performance progressively detoriated in terms of both reaction time and response errors, with an increased response time of approximately >500ms. Furthermore, the findings of Dinges and colleagues also suggest that the lack of sustained attention has a vital role in the performance deficits in many simple and complex cognitive tasks [Dinges & Kim, 2008].

However, previous studies found intriguing evidences of subjects' subjective performance of sleepiness and alertness [Dongen *et al.*, 2003]. The experiment exposed subjects to sleep restrictions of four, six, and eight hours time in bed for two weeks. Subjects who were exposed to four or six hours sleep restriction showed a decreasing performance in responses and behavioral alertness were near-linearly related to the length of accumulated wakefulness in excess of 16 hours, compared to the subjects who stayed eight hours time in bed. The subjects' subjective performance of sleepiness rating would initial increase, however, surprisingly after one week of sleep restriction, the subjective performance rating would stabilize although the measurements from the PVT showed a decreasing performance [Dongen *et al.*, 2003]. The findings suggest that people frequently underestimate the cognitive impact of sleep restriction and is often unaware of their level of cognitive and behavioral impairments, which has a significant role in self-management of fatigue and safety [Short & Banks, 2014].

Furthermore, research have also shown that sleep deprivation is associated with increase in negative mood states and diminished positive mood, with discrete emotions spanning from excitement, happiness, cheerfulness, activation, pride, as well as delight [Short & Banks, 2014]. Additionally, findings also suggest that the impact of increased negative and decreased positive mood was already after one night of sleep deprivation. The objective measurement was done with pupil dilation in response to emotional pictures, where as sleep deprived subjects' pupils were elevated as a response to negative pictures, which suggests a heightened emotional reactivity to negative emotional information when affected by sleep deprivation [Short & Banks, 2014].

The impact of sleep deprivation on cognition, sustained attention, and mood is likely linked to the effect sleep deprivation has on the neural systems that control these functions. Studies have revealed significant decrease in global glucose metabolism throughout the brain during sleep deprivation and it has been argued that these reductions in brain glucose metabolism play a vital role in functional deficits due to resource depletion during sleep deprivation [Short & Banks, 2014]. In addition, the brain region responsible for the transition between sleep and wake becomes unstable, after an extended period of wakefulness. The ventrolateral preoptic nucleus is the main region involved in the transition, and is often referred to the 'flip-flop' switch function between sleep and wake, and receives decreased inhibition following sleep loss [Saper *et al.*, 2005]. Other findings have shown the severe effects on the generation and survival of new neurons, particularly in the hippocampal dentate gyrus, the brain region involved in the formation of new memory [Guzman-Marin & McGinty, 2006]. The severity was demonstrated on adult rats who were exposed for 96 hours sleep deprivation, which led to approximately 50% reduction in the generation of new cells in the hippocampal dentate gyrus. Furthermore, subsequent to the sleep deprivation period, the development of mature and functional cells was reduced by 35%, and it is estimated that new neurons in this region is reduced by 60% due to sleep deprivation [Guzman-Marin & McGinty, 2006]. This indicates that recovery from sleep deprivation may not be a quick process and the effects of sleep deprivation on neurogenesis may not be readily reversible [Short & Banks, 2014].

Thus, sleep deprivation can lead to severe cognitive and neurobehavioral implications, and may have important implications in applied real world settings such as changes in driver behavior with slower response time, resulting from extended time awake. This also means, it is important to provide mechanisms for measuring performance changes resulting from time awake, sustained attention, and time-on-task.

2.1.2 Psychomotor vigilance test

The psychomotor vigilance test has become arguably the most widely used method for measuring behavioral alertness and has been used since the 19th century in sleep deprivation research, because the method offers a simple approach to track changes in behavioral alertness caused by the lack of sleep while excluding the need of aptitude or learning, due to its simple nature [Basner & Dinges, 2011]. In addition, the PVT applications are often easily accessible and does not necessarily require expensive equipment, compared to other methods such as the MSLT or MWT. The PVT setting relies on a stimuli (typically as visual cues) and a reaction time (RT, typically as a button press), but it also relies on sampling many responses to stimuli that appear at random inter-stimulus intervals (ISI) within a pre-defined range (in standard settings the interval ranges from 2 to 10 seconds), in which occurs over a period of time (commonly for 10 minutes). Thereby lies the 'vigilant' part from induced time on task and ISI parameterization [Dinges & Kim, 2008; Basner & Dinges, 2011].

Furthermore, the PVT also has merits in ecological aspects in which it can reflect real-world risks, because deficits in sustained attention and timely reactions adversely affect many applied tasks, such as transportation and many security-related operations, where lapses in attention measured by the PVT can occur when fatigue is caused by either sleep loss or time-on-task [Banks & Dinges, 2007; Basner & Dinges, 2011]. Previous research have shown sleep deprivation induces reliable changes in PVT performance, causing an overall slowing of response times and a steady increase in the number of errors of omission (the lapses of attention and often defined as RT>twice the mean RT, or approximately >500ms) and may also increase errors of commission (responses without a stimulus or false starts) [Basner & Dinges, 2011]. These effects can increase as task duration increase, and they form the basis of the instability theory [Basner & Dinges, 2011]. The theory hypothesizes that several competing systems influence the behavior during periods of sleep loss, where two of the most important ones are the involuntary drive to fall alseep and the counteracting drive to sustain alertness. This means, the interaction of sleep-initiation and wake-maintenance results in unstable sustained attention reflected through longer reaction time during PVT sessions [Basner & Dinges, 2011].

However, there is a considerable variation on the structure of PVT throughout the literature of published PVT reports. This includes task duration, specific performance metrics used as outcomes, and the platform on which the PVT was implemented. Thus, Basner and Dinges [Basner & Dinges, 2011] have proposed a formalized PVT framework with concrete design guidelines and ten PVT performance metric properties.

Design guidelines

Table 2.1 shows the guidelines in which Basner and Dinges suggest to use when implementing the PVT program.

For the standard outcomes, the individual raw RTs (in ms) are first divided by 1000/RT and then averaged. For the inter-stimulus interval, the guidelines suggest to randomly draw full second ISI, such as, 2, 3, 4, 5, 6, 7, 8, 9, or 10 seconds. Basner and Dinges further suggest that a block randomization would guarantee a fairly number of stimuli while keeping the random component of ISI, whereas otherwise long ISIs would result in a low number of stimuli. For the button fail-to-release and wrong key press, do not count as valid stimuli and thus do not contribute to the calculation of mean 1/RT.

It should also be noted that although the suggested duration is 10 minutes, results of previous experiments from Basner and Dinges indicate that for some outcome metrics, seems to be optimal for shorter than 10-min PVT durations, such as shortening the duration down to 3 minutes. However, as one of their limitations, the shorter duration has yet to be comprehensively examined and compared to the full 10 minutes duration. [Dinges & Kim, 2008; Basner & Dinges, 2011]

Outcome metrics

Basner and Dinges propose ten outcome metrics for assessing the analyses of PVT sessions. The Table 2.2 shows the ten different outcome metrics.

A PVT response is regarded valid if RT>100 ms., and responses without a stimulus or RT<100 ms., is counted as false starts (errors of commission). If RT>500 ms., then it is counted as a lapse (error of omission). Lapse probability is the number of lapses divided by the number of valid stimuli. Performance score is calculated by $1 - ((\textit{number of lapses} + \textit{false starts})/\ \textit{number of valid stimuli})$, the number of valid stimuli includes false starts.

Standard outcomes	Mean 1/RT and number of lapses
Stimulus	Visual millisecond counter in rectangular box.
Test duration	10 minutes. The test stops with the last response after an elapsed total time of 10 minutes.
Inter-stimulus internals	2-10 seconds. Defined as the period between the last response and the appearance of the next stimulus.
Feedback	The response time is displayed for 1 second. This period is part of the next inter-stimulus interval.
Errors of commision	Responses without a stimulus or response times <100 ms., 'FS' is displayed for 1 second. This period is part of the next inter-stimulus interval.
Errors of omission (lapses)	Response times >500 ms.
Time out	The milisecond counter times out after 30 seconds. without a response. 'OVERRUN' is displayed for 1 second. This period is part of the next inter-stimulus interval. And a sound is played back to alert the subject. The stimulus is counted as valid, i.e., as a lapse with a response time of 30 seconds.
Button fail-to-release	'BUTTON' is displayed after the response button has not been released for 3 seconds and a signal is continously played back until the button is released. The new inter-stimulus interval starts oncethe button is released.
Wrong key press	'ERR' is displayed for 1 second if the wrong response key is pressed. This period is part of the next inter-stimulus interval. If the wrong key was pressed prematurely, 'FS/ERR' is displayed instead of 'ERR'.

Table 2.1: *Guidelines for implementation of the 10-minute PVT.*

1.	Median RT.
2.	Mean RT.
3.	Fastest 10% RT.
4.	Mean 1/RT (also called response speed).
5.	Slowest 10% RT of 1/RT.
6.	Number of lapses.
7.	Lapse probability.
8.	Number of false starts.
9.	Number of lapses and false starts.
10.	Performance score.

Table 2.2: *Outcome metrics of the proposed PVT framework.*

The reasoning for RT<100 ms is counted as false starts is due to the *human processor model* [Wickens *et al.*, 2012]. In short, the model assumes that attention expands over four different processors, the perceptual processor, the cognitive processor, the motor processor, and the long-term and working memory. The perceptual processor handles the stored sensory input and attempts to recognize the data, e.g. letters, words, phonemes, icons. The long-term memory supports the recognition of the perceptual process in which it stores the memory of the different symbols. The cognitive processor handles the recognized symbols and try to make comparisons and decisions and is commonly known as the processor which does the 'thinking'. The cognitive processor may use the working memory section to store and alter symbols for the comparisons and decisions. Once a decision is made from the cognitive processor, an action is sent to the motor processor, to instruct the muscles for the execution of the action. [Wickens *et al.*, 2012]

Although the human processor model is a high level abstraction, the model provides numerical parameters supported from psychology studies, and results have shown that each processor has a cycle time (the time it takes to 'accept' one input and produce one output). Typically, the perceptual processor latency is around 100 ms $[50-200$ ms$]$. The cognitive processor is around 70 ms $[30-100$ ms$]$, and the motor processor is around 70 $[25-175$ ms$]$. Adding the three latencies together, the average cycle time will be around 240 ms [Wickens *et al.*, 2012]. Hence, the findings from the psychology studies accompany well with the findings from the PVT studies, in which non-sleep deprived results yielded approximately 250 ms in average response time and that a response time of 100 ms or less is very unlikely [Basner & Dinges, 2011; Dinges & Kim, 2008; Short & Banks, 2014].

In addition, Basner and Dinges suggest that the response speed, mean 1/RT, and the number of lapses, should serve as PVT primary outcomes. The reasoning is because the response speed property is very robust to extreme values, indicating its sentisivity to sleep loss and alertness decline among PVT measures. Lapses are a fitting outcome for reflecting state instability and have high ecological validity in regards to real world tasks with high attention-demanding, such as driving, while also being a common outcome metric in previous research. [Basner & Dinges, 2011]

2.1.3 Sleep and sleepiness applications

Fortunately, for the past recent years as technology becomes more accessible, particularly ubiquitous computing, the motivation for self-monitoring of health information has steadily grown. A report from the Pew Research Center [Fox & Duggan, 2012] showed that in 2012, 85% of U.S. adults own a cell phone and of those, 53% own a smartphone. Additionally, the report shows that in 2010, 17% of the cell phone owners in the U.S. were using their phone to access health information (e.g. monitoring exercises, diet, blood pressure, or finding information about the topics). In 2012, the amount of cell phone owners who were accessing health information with their phone was almost doubled. Exercise and diet applications are among the most popular types of health applications. Approximately, 38% of health users track their exercise, and 31%

monitor their diet. Other lesser popular applications consist of tracking weight, blood pressure, blood sugar, or medication.

However, when it comes to sleep and sleepiness applications, the results showed that approximately only 1% of the health users were using sleep applications. The staggering findings from the Pew Research Center report coupled with previous studies [Dongen *et al.*, 2003; Short & Banks, 2014] could indicate that people might not be aware of their own sleepiness and alertness, and thus have no initial incentive to use such applications. This notion is further strengthen by another study [Li *et al.*, 2011], where the findings suggest that people will first start to monitor their behavior when it becomes relevant for them, e.g. being diagnosed with diabetes, or execise to lose weight.

Furthermore, many ubiquitous sleep applications have been designed for functionality in mind rather than for an engaging user experience [Northcube, 2014; Azumio, 2014; Sleep Genius, 2014], or examples such as online PVT applications [of Sleep Medicine, 2014], where a person can test his reaction time through a visual stimulus online. However, the test sessions usually vary between 5-10 minutes in which the user interacts with a clinical minimal user interface, which might have a significant effect on time-on-task, since the measurement of sleepiness requires frequent test sessions [Banks & Dinges, 2007], people might lose interest or ignore the test altogether - further amplifying the findings from previous studies Li *et al.* [2011]; Dongen *et al.* [2003]; Fox & Duggan [2012]. Particularly the PVT duration might have a great influence on the user motivation, as studies from Basner and Dinges [Basner & Dinges, 2011] suggest that a shorter version of the PVT might increase the acceptance of the test where the commonly 10 minutes PVT is considered impractical.

A possible solution for user motivation and avoiding time-on-task for sleepiness applications, could be done by shifting the user's focus of doing the tedious test session to a playful task or provide meaningful incentives for doing the session. This can be done by implementing play elements found in play and games, in a meaningful way and in relation to the context, and is also often referred to the phenomena of *gamification*. Gamification is what the game designer, Jesse Schell, refers to as daily tasks which relate to some kind of game that would provide points and rewards based on our behavior to enhance user motivation and engagement [Schell, 2010]. Although the phenomena is still relatively new and only first after Jesse Schell's talk at the DICE summit in Las Vegas, Nevada, in 2010, that the term acquired greater relevance and attention where several articles from different fields were published, such as research related to marketing or human-computer interaction [Francisco-Aparicio *et al.*, 2013], there have been significant progress for common design principles, often noted in the form of the mechanics, dynamics and aesthetic (MDA) framework [Zichermann & Cunningham, 2011].

With the suggestion from Basner and Dinges in mind, a possible combination of a short version and full version of PVT might also be optimal with the combination of gamification. This means, the user could initially be presented with a short and brief version of the test, akin to an introduction or a 'quick-scan' session. And once the user is done with the session, the system could offer the user with the full version of the test if that is what is desired, while the gamification elements justify the combination.

Thus, in order to make sleepiness applications more attractive, it would be beneficial to take an approach akin to the successful health applications in which gamification is used. Nike Plus [Nike, 2014] being one of the very successful and popular health applications on the iOS smartphone, utilises various design elements to attract and maintain user motivation. The design principles of gamification heavily influence the application design decisions. And while the initial goal of Nike Plus was to generate brand loyalty and ultimately sell more sporting equipment, they thought very carefully about their user base and to whom the application would attract. The designers did simply not start assigning points and badges for buying Nike products, but instead sought to make running more engaging and fun in a meaningful way by using points and badges with social competition, in which would attract the running community, to then market their sporting products. [Zichermann & Cunningham, 2011]

In the case of Nike Plus, the social element is a strong and large part of the application. This is done by onboarding new users very quickly by introducing them to a simple first task as, 'Start a New Run', in which the novice can initiate and using the application as little more than a pedometer with a stopwatch. The novice user may then begin to compete against his best time or best distance, possibly use the leaderboard of his own runs to motivate and keep the interest. As the user continues to explore and use the application, new functionalities are presented. Runners are encouraged to connect to the social media platform, Facebook, and post their run information to their feeds. In addition, friends may comment and 'like' the feed and a notification is displayed on the runner's application along with a cheerful crowd sound effect. This may add an engaging social loop which reinforces the user's commitment to not only the fitness program but the application as well. Furthermore, Nike Plus also borrows elements from traditional play, such as runners can challenge each other in a 'tag' game. The goal may be to run fastest or farthest and the loser will become 'it'. The other users may then apply a witty trash-talk to the 'it', to encourage the tagged user to start a new challenge and tag someone else. [Zichermann & Cunningham, 2011]

Similarily, a sleepiness application could be designed to integrate gamification elements in a meaningful way, such as reward users with points and badges whenever they made a progression, possibly allow the users to submit their progression on a highscore list, for further social engagement, or provide users with various sleepiness performance lists and information about sleepiness, for enhanced feedback and reinforcement. Another possibility for gamification element is to provide users with daily challenges or small quests and reward them with customizable items and settings for the application, to enhance commitment and engagement. Thus, there are many possible solutions for gamifying a sleepiness application and hence, the next section of this chapter will investigate the literature of gamification.

2.2 Gamification

This section describes the MDA framework which is often used in the context of gamification. Firstly, a brief introductory review of the phenomena of gamification, followed by an outline of the three components of the framework.

2.2.1 The MDA Framework

In the recent years, gamification has become a buzz word in business and marketing. As in 2011 the market research firm Gartner, Inc. predicted that by 2014, *"...a gamified service for consumer goods marketing and customer retention will become as important as Facebook, eBay or Amazon, and more than 70 percent of Global 2000 organizations will have at least one gamified application"* [Egham, 2011]. Additionally, the market for gamification has steadily grown and according to the market research firm M2, the increase from 2011 to 2012 was approximately 42% and that the market would jump from $100M in 2011 to over $2.8B in 2016 [Research, 2011].

Furthermore, during the past few years gamification has also received the attention of the academia [Zichermann & Cunningham, 2011; Deterding *et al.*, 2011; Huotari & Hamari, 2012] and is starting to gain momentum where different research fields employ different definitions in relation to the point of view they examine it and its effect [Lounis *et al.*, 2013]. Huotari and Hamari define gamification from a service marketing perspective as, *"...a process of enhancing a service with affordances for gameful experiences in order to support a user's overall value creation"* [Huotari & Hamari, 2012]. Where as Deterding and colleagues define gamification as *"...the use of design elements characteristic for games in a non-game context"* [Deterding *et al.*, 2011]. Similarily, Zichermann and Cunningham describes gamification as a *"...process of game-thinking and game mechanics to engage users and solve problems"* [Zichermann & Cunningham, 2011]. Petkov and colleagues describe gamification as a *"persuasive technology"* in which attempts to influence user behavior by activating individual motives with game-like elements [Petkov *et al.*, 2011]. And as a consequence, gamification does not deal with designing games that can generally be defined as solving rule based artificial conflicts or simulations but rather related to *"serious games"* or *"games with a purpose"* [Deterding *et al.*, 2011; McGonigal, 2011].

Although no universally applicable defition exists, there are common design guidelines which are applicable and widely accepted for many design implementations, often mentioned as the *mechanics*, *dynamics* and *aesthetics* (MDA) framework. The MDA framework is often used in game design for postmortem analysis of the elements of a game, and can help to identify the use of system-thinking to describe the interplay of those game elements and apply them in non-gaming context. Mechanics refer to the core rules and functioning components of the game and allow a designer to guide player actions through the interaction of the UI. Where as dynamics describe the interactions of the mechanics on the subjective user experience over time, which can then relate to specific user motives, and evoke feelings and emotions as game aesthetics [Huotari & Hamari, 2012]. In other words, the aesthetics can be viewed as the composite outcome of the interaction between mechanics and dynamics [Zichermann & Cunningham, 2011]. Table 2.3 shows the MDA framework with examples of game mechanics and the relation to the dynamics and aesthetics.

As an example from Table 2.3, from a user's perspective, social exchange or recognition may play a vital role for motivation of using an application. Thus, it is essential for developers to

Mechanics	Dynamics	Aesthetics
Documentation of behavior	Exploration	Intellectual curiosity
Scoring systems, badges, trophies	Collection	Achievement
Rankings and leaderboards	Competition	Social recognition
Levels, reputation points	Acquisition of status	Social recognition
Group tasks	Collaboration	Social exchange
Time pressure, tasks, quests	Challenge	Cognitive stimulation
Avatars, virtual worlds	Development/organization	Self-determination

Table 2.3: *MDA framework examples [Blohm & Leimeister, 2013].*

create mechanics which support dynamics that can evoke social exchange and recognition. In this case, a possible solution would be to implement a points system where users are tasked with different challenges and reward them with points once a task is completed. Extending the point system could introduce the users to leaderboards, rewarded points could depend on the performance, or allow tasks to be completed with other users, encouraging the dynamics of collection, competition and/or collaboration.

2.2.2 Mechanics

The described mechanics in this report follow the seven proposed primary elements from Zichermann and Cunningham [Zichermann & Cunningham, 2011] which are; points, badges, levels, leaderboards, challenges and quests, onboarding, and engagement loops.

Points

Points are important regardless of whether their accumulation is shared among users or between the application and the user, as they are the basic scoring units for measuring progress in gamification. By utilizing points, users can claim rewards, cash them to advance in the game, accumulate them to be listed in a ranking for social competition or for collection motives. Hence, points are the very corner stones of the gamification elements. [Zichermann & Cunningham, 2011]

Badges

Another strong gamification element is the use of badges. Likewise points, badges serve to reward users as well as recognize their achievements and accomplishments. Furthermore, they are also a powerful tool for signaling social status and can serve as a drive for collection as well. Points and badges are often interrelated, meaning that once the user has accumulated a certain amount of points, they may be awarded by badges as a result for their accomplishment. [Zichermann & Cunningham, 2011]

Levels

Levels or milestones is often used to indicate progress, although in the context of gamification, levels may not represent traditional levels found in games such as in Super Mario World [Nintendo, 2014], where each level is clearly outlined with distinct layout and numbered stages, but rather markers for users to know where they currently stand in a gaming experience over time. Furthermore, badges can be offered at every milestone and in such way enhance the goal orientation in the game and signify achievement. [Zichermann & Cunningham, 2011]

Leaderboards

Leaderboards bring in the social aspect of points and badges. This can be done by displaying the accumulated points besides players' username in a highscore list. Leaderboards can be tailored to specific purposes and user groups, since not all users may be interested in the competitive nature of a highscore list. Therefore, the context plays a vital role for designing the proper leaderboards for an application, and may even contain more than one leaderboard, such as one leaderboard for the overall highscore and one for a local highscore among friends. [Zichermann & Cunningham, 2011]

Challenges and quests

A powerful game mechanic to keep users focused on a game and to stay engaged and interested, is to provide them with various challenges or quests. This can be introduced in many forms such as time pressure, increasing difficulty on actions or specific and special way of solving a problem. An example of how strong the challenge element may appear was the public challenge experiment hosted by researchers from the University of Washington, where they challenged the public to play the game, Foldit. The game was focused around protein folding, to provide vital clues on how to prevent or treat diseases. Researchers had worked on a protein problem for over 10 years and had yet to solve it, where as the problem was solved in 10 days after the release of the game by 46.000 volunteered users. [Kumar, 2013; Zichermann & Cunningham, 2011]

Onboarding

Through onboarding, the game helps new users and novices to transition to expert users and as a result, the game sustains the user engagement. This can be done by offering help in the form of tips and hints, difficulty adjustment, and a brief introduction to the game mechanics. Failing to onboard the user when the challenges are significantly higher than the user's skills, may leave the user with high anxiety and as a result, makes the user give up. [Zichermann & Cunningham, 2011]

Engagement loops

Zichermann and Cunningham suggest four engagement loops, motivating emotion, social call to action, player reengagement, and visible progress and reward. Motivating emotion refers to the motivation to use an application. Social call to action refers to the participation in a social interaction or event. Player reengagement is the motivation factors that pulls the user back to the applications, and visible progress and reward refer to the recognition of participation of the challenges or quests, which then begins a new loop of engagement. [Zichermann & Cunningham, 2011]

2.2.3 Dynamics

Dynamics are often referred to the run-time behavior of the mechanics acting on player input and interactions with other mechanics. For example, from Table 2.3, challenge can be raised by putting on a time limit or increases the complexity of tasks. Collaboration could be evoked by encourage information sharing across certain members or supplying winning conditions that are more difficult to achieve alone. Collection and development could encourage users to purchase or earn game items, for designing, constructing and changing levels or worlds and for personalizing unique avatars. Other examples such as to encourage exploration, the game could track the progress and show the user which tasks, paths or items that have yet to be discovered or earned. To evoke competition, the obvious attempt would be to present the users with a highscore list, while other options could include a more direct approach in the form of run-time score notifications from other users or friends, after a performed task. [Blohm & Leimeister, 2013; Hunicke *et al.*, 2004]

2.2.4 Aesthetics

Aesthetics are the emotional responses evoked in the player, such as sensation, fantasy, fellowship, narrative, and is a vital part in understanding the user and the motivation for using the application. Psychology typically refers human motives as *intrinsic* and *extrinsic* motivations. Intrinsic motivation is defined as *"...the doing of an activity for its inherent satisfactions rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards"*. Where as extrinsic motivation is described as *"...a construct that pertains whenever an activity is done in order to attain some separable outcome. Extrinsic motivation thus contrasts with intrinsic motivation, which refers to doing an activity simply for the enjoyment of the activity itself, rather than its instrumental value"* [Ryan & Deci, 2000].

Traditional incentive mechanisms are usually based on increasing extrinsic motivation, such as introducing financial rewards. However, such stimuli often fails to sustain motivation in the long run as adaptation effects undermine their effectiveness [McGonigal, 2011]. Fortunately, with digital gamified applications it is possible to arouse the intrinsic motivation of users as well. This can be done in various ways, and even extrinsic incentives can systematically activate flow and intrinsic motives [Ryan & Deci, 2000; McGonigal, 2011]. Thus, incentives such as badges and points do not only apply to intrinsic motivation of collection and achievement, but also to extrinsic motive of gaining social recognition [Blohm & Leimeister, 2013]. This means as a result, gamification allows design for persuasive incentive mechanics that go far beyond traditional financial incentives and in addition, Ortiz de Guinea and colleagues suggest that gamification has a high potential for changing behavioral patterns [Guinea & Markus, 2009]. By evoking continous appropriate stimuli through positive emotional feedback, gamification can be used as a tool to support the introduction of new patterns of behavior as well as affecting habitual behavior, while traditional incentive frequent schemes often only yields a low effectiveness [Blohm & Leimeister, 2013].

Four Player Types

Richard Bartle proposes four primary player types for understanding game motivations regarding intrinsic and extrinsic motives. Understanding the four player types can greatly assist on creating the gamified application to suit each user's motives. The player types are *socializers*, *achievers*, *explorers*, and *killers* [Stewart, 2014; Bartle, 2014]. Originally, the four player types were developed by studying players of massively multiplayer online games (MMO) and since then, the player types have expanded to more than four types, however, the four player types remain arguably the most important ones for gamification purposes [Zichermann & Cunningham, 2011]. Figure 2.1 shows the four player types.

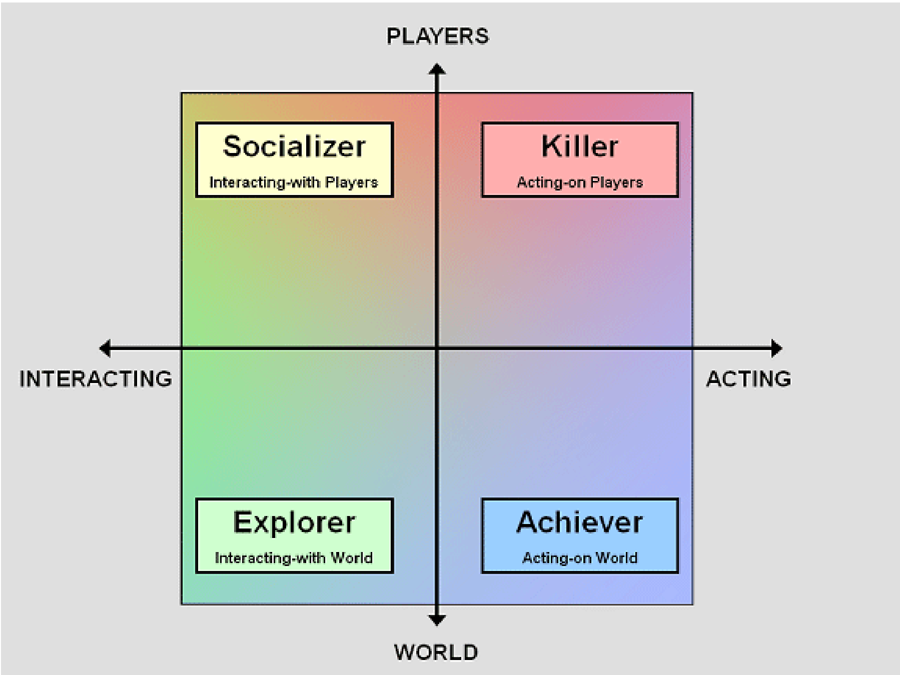

Figure 2.1: *Visual representation of the four player types [Stewart, 2014].*

However, it should also be noted that, the types are mutually inclusive, which means not all users are strictly one type and often have characteristics of all four types with variation for each type and may even vary from application to application [Zichermann & Cunningham, 2011].

Socializers

Users who mostly fit into the socializer category play games for the benefit of a social interaction and the drive is to develop a network of friends and contacts. Although socializers can still be interested in the application or winning, since the game acts more as a catalyst for meaningful long-term social interactions and not the end in it-self [Zichermann & Cunningham, 2011]. For example, looking at Table 2.3, group tasks, avatars and virtual worlds are common mechanics for invoking social dynamics. However, if an application offers certain social interactions or rewards through competition or exploration, socializers may also be motivated to participate in such activities in order to gain the social benefits.

Achievers

Achievers like to accumulate points and rising in levels as their main goals, often as quickly and/or complete as possible. This accomplishment is often reflected through badges, levels or leaderboards in which achievers take great pride in their formal status', presented by the game's built-in ranking hierachy [Stewart, 2014]. Comparing to Table 2.3, this means, leveling up, leaderboards and accumulation of vast quantity of looted items are all mechanics which evoke dynamics of collection and status, resulting in achievement and social recognition motives for achievers. Another strong aspect of an achiever is the persistent nature for accomplishing the goals. Meaning, mechanics such as lengthy tasks and quests could be rendered as non-challenging for the cognitive stimulation and as a result not enjoyable for the other player types, while achievers may endure the 'grind', if the game rewards the progress proportionally to the amount of effort invested [Stewart, 2014].

Explorers

Explorers find and seek pleasure in discovering the different patterns and structures of an application. This can range from simple content exploration to knowledge-seeking and strategic planning. Understanding the principles and levers behind the revealed data is a reward in its own, with further enjoyment when sharing the knowledge to others while no extrinsic reward for doing so is often not needed or expected [Stewart, 2014]. Bringing back the example of Super Mario World, while achievers may want to complete the game as fast as possible, explorers would seek to find the many hidden 'pipe-levels' scattered throughout the stages, which would require several playthroughs, to then pass on the knowledge to their peers or community. Likewise, if the gamified application has a large enough userbase to have its own social community bulletin board, explorers would often be the ones behind the user created guides and tutorials for the application. Thus, explorers can act as a strong asset for bringing in new users and lift novice users up to expert level through peer-to-peer guides, resulting in sustained motivation for using the application [Zichermann & Cunningham, 2011].

Killers

Killers are similar to achievers in their desire to win, however, killers instinctively will try to find and exploit advantages in order to do so. They are the tool-users, the adrenaline junkies, the natural politicians, the combat pilots, and the high-stake gamblers. Moreover, killers like to provoke and cause drama or impose them over other players in the scope provided by the game [Stewart, 2014]. An example, from the Social Game Developers Rant of the 2011 Game Developer Conference, where attendees were asked to play a social game which goal was to collect as many coins as possible from other attendees [Reighton, 2011]. The achiever would play by the rules and race around the audience asking for their coin, the socializer would use the dynamics as a mean to meet new people or help others to win, the explorer would sit quietly and analyze and try to understand the flow of coin exchange, while the killer would instantly try to circumvent and exploit the designed system to achieve the goal. In this case, a conference associate which held one of the bags of coins was persuaded to hand over the whole thing to an attendee, and 'won' the game as a result, while it was technically against the rules to grab the whole bag from a conference associate [Stewart, 2014]. The attendee did not felt he was cheating, and when it was time for the audience to count the amount of gathered coins, he proudly revealed the bag of coins for the audience to admire and acknowledge his accomplishment, in which the nature of the competition was the main thrive of motivation.

2.3 Summary

This chapter examined the severe impacts of sleep deprivation on cognitive and neurobehavioral implications. Where among the consequences are the ability to maintain sustained attention with an increased response time. This is particularly severe for high attention demanding tasks, such as traffic driving or security related operations. Fortunately, the literature suggests several methods for self-report and monitoring the sleepiness state, where among the common methods is the psychomotor vigilance test (PVT). The PVT is an active visual stimuli response input, meaning the user must respond to an active visual stimulus whenever it occurs and the application will then log the response time. Furthermore, Basner and Dinges suggest a standardized framework for the application setting with specific outcome metrics. Among the important settings for the PVT;

- 10 minutes duration.
- RT>500 ms counts as a lapse.
- RT>30000 ms counts as a time out.
- RT<100 ms counts as a false start.
- Input without active stimuli counts as a false start.
- Randomized inter-stimuli interval.

In addition, among the important outcome metrics are the *number of lapses* and the *mean response speed*, also known as the reciprocally transformed RT (1/RT). However, the literature also indicates that the PVT in its full length might not be very practical for use outside of laboratory settings, due to the nature of the task in combination of the duration. Fortunately, as ubiquitous computing becomes more common with an uprising growth for integrating motivational and game play incentives in non-game applications, a possible solution is then to apply such incentives into a PVT application to shift the focus away from doing a tedious task. This phenomena is often referred to gamification.

Gamification borrows many game design elements and often contains a three part framework. The mechanics, dynamics and aesthetics framework.

- *Mechanics* refer to the underlying functions and rules of the application, and often serve as a mean to reward the users after completing specific objectives or goals. Among common mechanics are, points, badges, levels, leaderboards, challenges, quests.
- *Dynamics* often refer to the interaction between the user and the application.
- *Aesthetics* refer to the experience and emotional state that is evoked through the dynamics and mechanics.

Aesthetics has an important part for users' incentives of how motivated and encouraged they are for using the application. This is typically divided into two different motivation categories, *intrinsic motivation* and *extrinsic motivation*. The two categories in combination with different mechanics and dynamics, may evoke different player types with different motivations for using the application. Richard Bartle proposed four overall different player types for games, the socializer, the explorer, the achievers, and the killers. Although the four player types are roughly an overview and generalization, they suit well with the purpose of a gamified application with the commonly used mechanics and thus appeal and motivate differently for each player type.

Thus, with the literature review in mind, the next chapter, Chapter 3, describes the application design. This includes the reasonings of the different features and how they are supposed to encourage each of the different player types.

Chapter 3

Application Design

This chapter describes the design process of the implemented application and the reasonings behind the various design decisions with emphasis on the obtained knowledge from the literature review as guidelines. In addition, the chapter also discuss the relevant points taken from an interview with Jan Ovesen, MD. Head of Innovation and Development of MEDEI. See Appendix A for the full interview. The conducted interview served as a method for validating the proposed framework from Basner and Dinges, in addition to exploring possible options for adjustable and changeable elements regarding the PVT design criterias, for creating a varied gameplay experience and thereby possibly maintain users' interest and motivation in the application.

3.1 The Premise

The premise of the application is quite simple as it is centered around the setup and procedure of the PVT. This is particularly true since the implemented application follows the proposed design guidelines of PVT from Basner and Dinges, with the suggested design criterias and outcome metrics. However, some minor intentional adjustments have been made, in regards to context and gameplay, for the gamified version of the PVT. These changes are mainly on the visual part of the user feedback, adjustments such as on how the reaction time is portrayed and that the system only has one clickable button for the active stimulus (resulting in always hitting the right button when an active stimulus is present). This means, the core gameplay for the user is essentially performing a PVT, while of course, the gamification elements are supposed to support and maintain the motivation for keep playing and shifting the focus away of 'doing a tedious task'.

3.2 A Bear Setting

The initial idea with a possible setting was something that had to be related to sleep or sleepiness, while also containing elements of sustained attention as well as the core setting of PVT. Starting with dissecting the core setting of PVT, namely that the user waits for an active visual stimulus to occur and then tries to react as fast as possible to the stimulus by giving the system some sort of input, in this case, a simple click or tap.

Since the concept is very broad and relatively unrestricted, various gameplay ideas occurred. The first idea was that the PVT can roughly be considered the same as the classic arcade game, *Whack-A-Mole*, in which the user also waits for a visual stimulus to occur and that the user 'whacks' the stimulus as soon as it appears to gain a score. The setting is also almost identical to the PVT setting with the obvious exception of audiovisual but also the score system in which the original Whack-A-Mole game only logs the number of whacked moles, and do not count such metrics as reaction time or number of misses (lapses). Fortunately, since the application is in the form of digital media, the score system could easily be adapted to also contain the additional outcome metrics suggested from Basner and Dinges, while still maintaining the overall flow of the gameplay. While the concept of a Whack-A-Mole game would most likely trigger a familiar feeling in many users, the drawback would however then be the difficulty of keep bringing something non-generic content or new to the table.

Continue on from the brainstorming session with the Whack-A-Mole concept as a start, an extra design criteria appeared as a result, namely that the concept should be something unusual and yet familiar enough for the user to create a relatable connection. This brought up two new concepts with nature inspired themes; flowers catching sun, and a huntsman hunting ducks.

The idea of flowers catching sun was that 'bubbles' of sunlight would fall down from the sky and then it was the user's task to click on them in order for the flowers to grow. The amount of growth per sunlight bubble would then vary depending on the reaction time. In addition, the user would then be able to purchase different flowers and possibly plant the flowers in different 'gardens', to create the sensation of new and different game content. The second idea, hunting ducks, would be akin to real-life duck hunting, where the huntsman wait patiently till the ducks are flying in the air and then pulling the trigger in a fast and accurate manner in order to hit the bird. A different take on the concept could also be like a more humoristic setting akin to shooting games found in traditional festival events or circus, where cutout paper figurines move in a horizontal line and that the user tries to knock them down with a toy rifle. The idea would then be, rewards would depend on the performance and how many ducks or paper cutouts were shot.

While the concepts support the new design criteria, the ideas lack the connectivity for why it should be relevant for sleep and sleepiness, or indicating any severe consequences for that matter in regards to PVT and perceived safety of sleepiness and sustained attention. However, the idea of having an object that comes in different forms or variation for creating various gameplay experience sounded very appealing and thus kept in mind.

This brought up another idea, inspired by the harsh nature of wild animal predators on the hunt. An example such as if a lioness is not attentive enough about when her prey has detected her, she might miss the right timing to strike and the prey would escape. Another example would be if a bear is standing in a river and is trying to catch some fish, and if the sustained attention of the bear is low, the fish might be able to slip by and avoid getting eaten. This is very likely when the predators are tired or have not eaten for days due to failed hunts, resulting in fatigue and low attention and possibly starvation as well.

Although the application design might not be as directly harsh as real-life hunts, the idea of a bear hunting for fish was a very appealing idea, since the concept of a varied reward and progression system could easily be integrated into the gameplay, for example in the form of different fish and locations. Furthermore, the caught fish could also vary depending on the reaction time, meaning a good performance yields a big or rare fish while a poor performance yields a smaller fish. In addition, the concept also assumes that many users are probably already familiar with the image of bears fishing at river sides or close to a small waterfall edge waiting for salmons to jump into their mouths, due to animal documentary movies. The familiar feeling also contributes to a faster onboarding user experience. Thus, the severe consequence of sleepiness is mainly represented subtly by the variation of fish caught, while still logging the proposed outcome metrics for a deeper analysis.

3.3 Objectives

Derived from the setting, the gameplay's main objective is to catch as many fish as possible in the levels and preferably catch the 'rarer' fish by having good performance in reaction time. On another note, the application's objective is to keep the users playing and attracting new users as well, to essentially performing PVT sessions by playing the different levels. This core loop is supported by four primary features; the play system, the level up system, the badge system, and the friends and social system. All four features are represented by visual interactive icons on the 'home' screen as the first thing the user will see whenever the application is started. Figure 3.1 shows the home screen of the application, with the four features distinctive outlined.

Figure 3.1: *Screenshot of the home screen.*

Play system

The fishing rod shown in Figure 3.1 represents the play system and is essentially acting as a play button. This means, when the user clicks the button, a new window will appear asking the user which stage should be played. Figure 3.2 shows the level selection window in which the user can browse through the different stages and then decide where the next adventure should be.

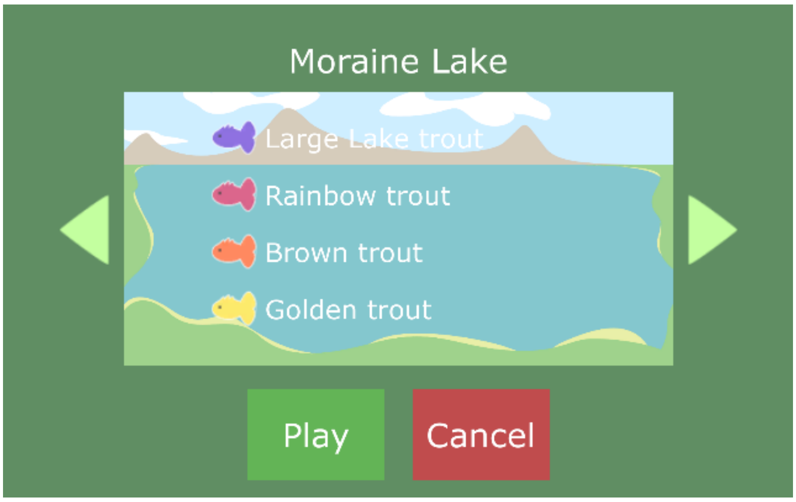

Figure 3.2: *Screenshot of the level selection.*

Each stage is supposed to represent real world locations and the catchable fish are related to the locations, meaning to catch a specific fish, the user would have to select the specific stage in which the fish inhabits. This mechanic encourages users to try out different stages with relatable content and thereby attempt to maintain the user motivation. Once a stage is selected, the application will start the underlying PVT session where the user is presented a scene with the correct visuals of the selected location. Figure 3.3 shows an example of in-game selected location.

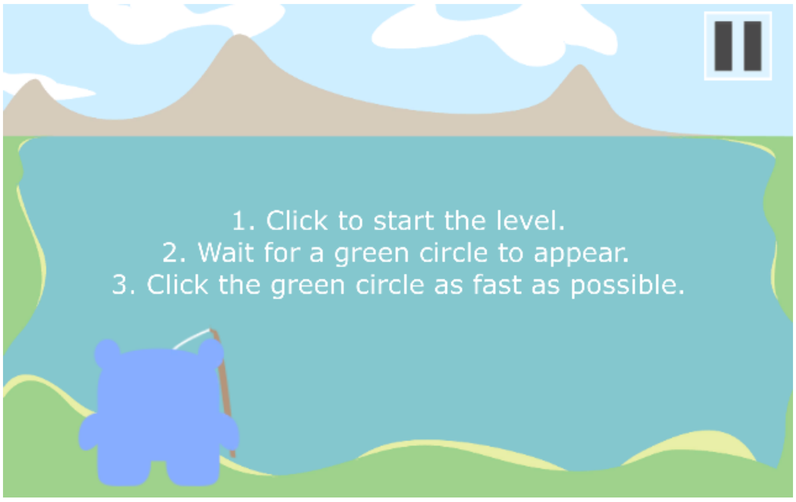

Figure 3.3: *Screenshot of a selected level.*

During the PVT session, the user will interact with visual stimuli appearing as colored circles. A green circle means an active stimulus and a red circle means a false start or a time out. Whenever the user interacts with a green circle, a fish will appear and is caught and its appearance will depend on the reaction time. The green circle should be portrayed as like water droplets hitting the surface of water, creating small wave ripples. Figure 3.4 shows an example of a caught fish.

Once the PVT session is done, a window will appear displaying how many fish the user caught but also providing the option to view the performance of the outcome metrics regarding

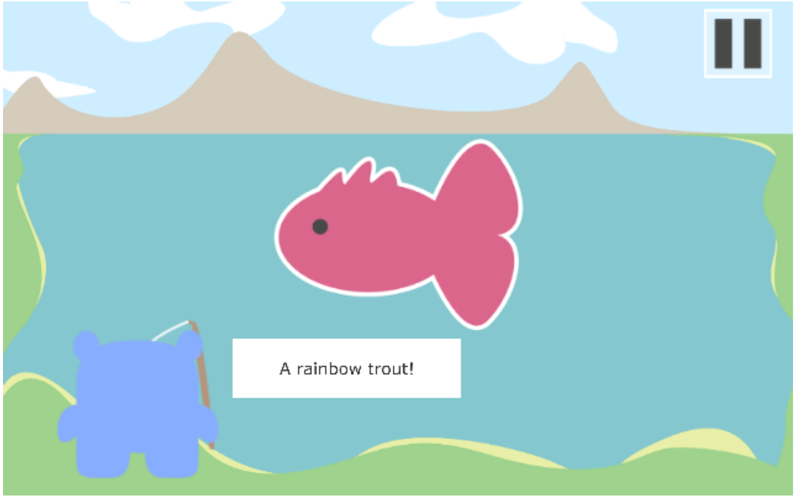

Figure 3.4: *Screenshot of a caught fish.*

the PVT. This is simply done by clicking on the *stats+* button to bring up the PVT outcome metrics, and clicking the button again will take the user back to the amount of fish caught. Figure 3.5 shows an example of the end screen with how many of each fish the user caught, and Figure 3.6 shows an example with the screen of PVT outcome metrics

Figure 3.5: *Screenshot of the end screen, displaying how many of each fish the player caught during game session. This is for the game play experience to keep the user immersed in the game world.*

Level up system

The pile of fish lying on the cave floor on the home screen represents the level up system. This feature is supposed to create a feeling of progression, meaning the caught fish from the different stages can be 'consumed' to gain *experience points* and if enough experience points are accumulated, the bear will increase in level. The amount of experience point each fish yields depend on the fish's tier, since each fish belongs to a tier which is essentially determined by the reaction time of a single active stimulus instance. Meaning, the faster reaction time, the better fish tier and ultimately more experience points. The levels are needed for unlocking new locations and places, as many of the locations require a specific minimum amount of levels in order to play.

Figure 3.6: *Screenshot of the screen, displaying the PVT outcome metrics suggested by Basner and Dinges. This is for the 'technical stuff behind the scene' accessible for those users who are interested in a deeper analysis of their own performance.*

Thus, the mechanic is supposed to attract explorers that like to discover all the game's aspects and levels while still maintaining a sensation of progress. Figure 3.7 shows the screen for the level up system.

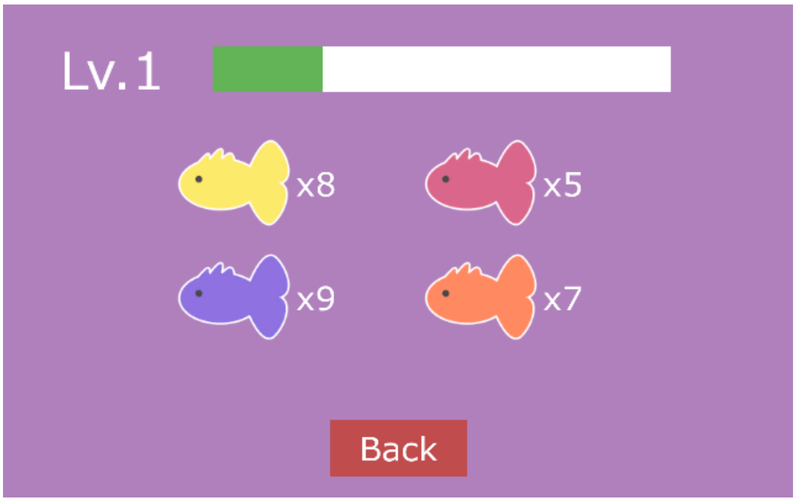

Figure 3.7: *Screenshot of the level up system.*

Badge system

The golden fish trophy on the wall on the home screen represents the badge system. Once the user clicks on the interactive icon, a window will appear where the user is presented with various obtainable badges. At the very start when a new user profile is created, all badges are initially locked and in order to unlock badges, specific challenges must be completed. The challenges are varied and can range from simple tasks such as, 'catch a fish from this location' to more complex or challenging feats such as, 'achieve this performance score' or 'catch this many specific fish'. Figure 3.8 shows the screen for the badge system.

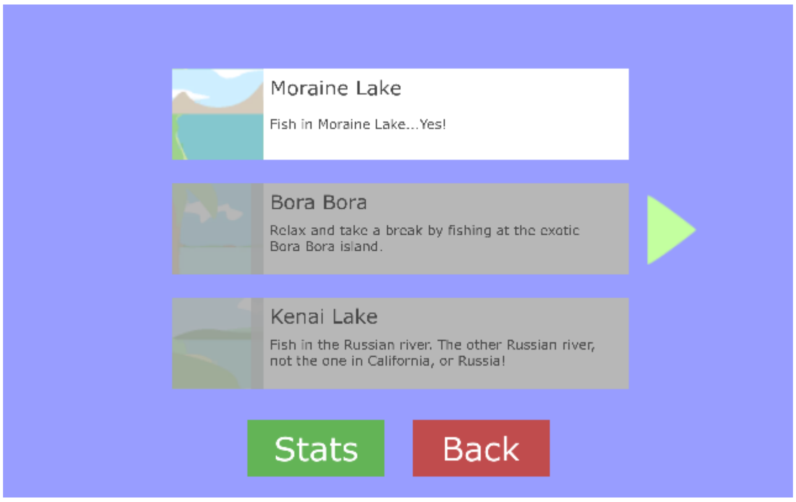

Figure 3.8: *Screenshot of the badge system. In this case, the 'Moraine Lake' badge is already obtained and unlocked while the two other displayed badges are still locked.*

The badge system is supposed to encourage users who like to collect and achieve, by rewarding them with various badges for their accomplishments. Thus, besides of leveling up from consuming caught fish, the badge system provides additional incentive for progression.

Friends and social system

Social interactions is represented by the hidden bear icon, where users will have the option to watch activities of other users and send small encouraging messages to their friends. This is done by having two separated windows. One window for a 'Facebook-like Wall', where the user can see activities from other users. Activities such as, information of newly completed stages or newly obtained badges. In addition, the user has the option to make a small response on the feat as a public comment. The second window provides information of the user's friendlist and handles an overview of information such as which friends are currently online. The feature is supposed to encourage and enhance the social loop of the application, and thus attempt to appeal towards socializers as a strong incentive feature. Furthermore, as like with many other applications with a social aspect, the application could also contain a button or a link which would open a new window and bring the user to a bulletin board (forum). Here, users would be able to post and discuss various topics to greater extend, such as creating user guides or bragging about their new feat, thus also attracting the explorers and achievers.

3.4 Audiovisual Feedback

The general art style is kept very minimalistic and 'cartoonish', for the sake of simplicity. In addition, emphasis has been put on the interactive feedback between user and game objects, meaning whenever the user interacts with an object, the system will always respond with an audiovisual cue. This is important to create the illusion of a 'live' game environment but also that the system in general is responsive towards user input.

Ranging from obvious feedback example such as, when an active stimulus is clicked, a fish or a red circle will appear, indicating that the system has accepted or declined the user input, respectively, as a valid response time. More subtle audiovisual feedback would for example be, once the user clicks on the active stimulus, a small appropriate audio file is played along with a bunch of small spawned particle effect occuring around the fish, and that the fish receives a small translation and rotation as well. In addition, the bear character would provide with an appropriate respond to the user input. This strengthen the effect of a responsive system and a lively game environment. And by implementing such subtle feedback systems, the focus of the tedious task of performing the PVT might be shifted towards a more enjoyable experience in the form of play and pleasant game feedback.

3.5 Interview With Jan Ovesen

With his 31 years in the profession, Jan Ovesen was among the pioneers in Denmark in the '70s that were working with children who suffered under the condition of sleep apnea, which was still relatively new in the field of research. Since early '00 the focus has extended to other sleep disorders as well, including sleep insomnia. And because PVT is a common method for measuring the patients' sleepiness state, Jan Ovesen has great experience with patients performing PVT sessions. This means, in regards to this chapter and the interview, two general topics are discussed. The first topic being the validation of the PVT setting, and the second one is the degree of freedom for gamification.

Before the interview, a demo of the application was presented, featuring the most vital audiovisuals and functionalities. This was supposed to be sufficient in order to create an overall impression of the game design and gameplay. Furthermore, the presentation also included a few minutes of gameplay where Jan Ovesen tried the underlying PVT session, in addition to have a look at the end screen with the caught fish and outcome metrics displayed.

3.5.1 PVT design criterias

Starting with the validation of the PVT setting, a question was asked for what his experience was towards the 10 design criterias, shown in Figure 2.1. In general, he agreed on all of the proposed design criterias, however, did also note that the current research for a standardized framework is limited and thus many of the criterias are stepping stones. Such example is the presentation of the stimulus, being millisecond counter in a rectangular box, or the feedback that is displayed for 1 second after input. An adaptation or alternative solution could possibly exist as well.

Duration

In addition, he thought that the 10 minutes duration is important because *'...the duration is long enough to overcome the acute 'energy kick' for subjects that are more than 24 hours sleep deprived. The extra reserve of energy is something we all have for use in dire or emergency situations, however, the extra reserve of energy will rapidly depletes, particularly if the situation is a repetitive task. This has been shown in previous research, that the first 2-3 minutes, the person respond normally, and after the 3-4 minutes, the reaction time steadily decreases.'*

Inter-stimulus interval

On the note for why the ISI is proposed to be 2-10 seconds, Jan Ovesen answered the question with *'...2-10 seconds sounds reasonable, because the stimulus itself has a little arousal effect on the brain and it takes some time for the brain to balance out the arousal. Which is why 2-10 seconds are used here, however, it is also possible to make the ISI longer, as seen in some previous studies.'*

Errors of commission

For errors of commission, he mentioned that *'...if a test person simply keep clicking the button without any stimulus active, he might at one instance hit the button with RT less than 100 ms, and this is of course due to the continuous clicking and less about reaction time.'*

Time out and errors of omission

And for the timeout and errors of omission criteria as *'...if the RT is over 30 seconds, that would indicate a high risk of falling asleep. And the error of omission would indicate a decreased response time and possible sleep deprived, compared to persons without sleep disorder.'*

3.5.2 PVT outcome metrics

Next, a question was asked regarding his experience with the 10 outcome metrics, shown in Figure 2.2. He noted that the outcome metrics are important but some might be more relevant depending on the situation and that the provided outcome metrics is a strong starting point and toolbox for a standardized framework. His experience has mainly been on the reciprocally transformed RT and the number of lapses, as he mentions *'...the response speed is great for providing an overview of their sleepiness state regarding reaction time for repetitive task oriented work. The number of lapses is great for indications of risk for falling asleep'*. And continuing on by noting why it is relevant for measuring the patients' sleepiness state objectively, and the answer corresponds well towards the review from the literature, *'...patients have even told me during tests that they were surprised about even missing several seconds of a stimulus or altogether, resulting in a time out. This is often because the overestimation of their own sleepiness state, they would rate themselves as not sleepy while the numbers show otherwise. Which is also why it is important to measure the sleepiness state objectively, otherwise the patients would hardly believe it for themselves, particularly those who suffer sleep deprivation.'*

3.5.3 Degree of freedom for gamification

Moving on to the second topic, concerning the degree of freedom for gamification, the first question was about how much changeable and tweakable the design criterias are allowed to be in order to create a varied gameplay experience. The answer was simply to test them, *'... since many of the factors are still relatively uncovered regarding different settings'*. However, he did note that the ISI needs to be randomized in an interval but may be in different ranges. And even less freedom for the false start and lapse because, *'...that is more a neurophysiological matter, as how fast a normal reaction time is supposed to be.'*

The next question was regarding the reaction time, for implementing a feedback system that takes different threshold limits into account and reward the user accordingly, depending on the reaction time. For that, Jan Ovesen noted it could be interesting to test the threshold limits on different users, such as *'...young and elderly people with good sleep, and patients with good sleep...so that if a person that is heavily sleep deprived would play a stage that has different thresholds for the fish than a person without sleep deprivation, to give a chance to the heavily sleep deprived person to catch the bigger fish as well.'*

The suggested idea of implementing and testing out different settings were quite appealing, however is something that is excluded in the current iteration due to time and resource management and acts more as design specifications for future work.

3.6 Summary

This chapter examined the reasonings behind the design decisions of the application. Where the concept of a bear fishing for fish were appealing enough to generate various gameplay experience in the form of different locations and catchable fish. In addition, three vital features were designed to support the gameplay and keep users motivated in doing the underlying PVT sessions. Each of the three features are supposed to encourage the different player types from Bartle's Four Player Types, from Figure 2.1.

- A level up system which encourages both explorers and achievers to use in order to unlock new locations and fish, to generate a new gameplay experience.
- A badge system which encourages achievers to complete certain objectives in the different stages and reward them for their accomplishments.
- A social and friend system which encourages explorers, achievers, and socializers to actively use, for checking up how their friends are doing. In addition, badges and achievements would also be displayed for each accomplishment and feat, which could strengthen the social status and recognition and particularly appeal to achievers. The system could also link to a forum in which more in-depth discussion would take place, and as a result, possibly attracting explorers as well.

The PVT setting were validated through the interview with Jan Ovesen, MD. Starting with the design criterias which were noted as applicable since many of the design criterias stem from past PVT setups. However, it was also noted that the design criterias might allow to be changed or adjusted to fit the need of a gamified application but would require a test iteration for evaluation. This was particularly for reaction time, as it could be adapted to users' sleepiness state, meaning the threshold limits for each fish tier would change in a fair matter so that all users have equal chance to catch all fish tiers regardless of sleepiness state. Furthermore, it was noted that the outcome metrics consist of relevant variables while the response speed and the number of lapses were noted as the very strong factors toward measuring the sleepiness state, as mentioned in literature as well.

Now that the application design has been examined and the PVT design criterias have been reviewed, thus the next chapter, Chapter 4, will discuss the current implementation of the application.

Chapter 4

Implementation

This chapter describes the implementation process with the more technical aspect of the application and which limitations that had to be chosen due to limited time and resource.

4.1 Technical Specifications

The application is powered by the game engine, Unity3D [Unity, 2014], and the scripting is primarily done in the programming language, *C*#. The current implementation support both keyboard and mouse but also single touch input, for interaction.

4.1.1 Delegates and events

In Unity3D, for two objects to communicate with each other, a reference is needed and if an object needs to communicate with many different objects, it often leads to a large list of references and can quickly turn out to be a bookkeeping nightmare. Which means the initial requirement of finding the object is either by string name, tag, or type, and as in worst case, if one of the references' object is destroyed and then called, the reference would first need to be reattached to a new object in order to avoid an exception and null reference. An alternative solution for large list of object references, the application heavily relies on the use of `delegates` and `events`. This provides an easy method for referencing between game objects without the need for finding the specific object and its attached script. Although some care still has to be taken in the form of disabling the broadcast when the object is destroyed. Fortunately, disable the broadcast can easily be trivialized by always include the methods in the `OnEnable`() and `OnDisable`() methods in the class with the corresponding `delegates` and `events`.

4.1.2 Time manager

The `TimeManager()` class handles all the time related PVT settings, such as the total duration, active stimulus, reaction time, ISI, false start, and time out. Duration is currently 10 minutes for each stage, but it is possible to quit the stage prematurely. The class utilizes the `Stopwatch()` class from *C*#.NET, to create and count the different timers. There are four stopwatches in the time manager class, a level duration, an ISI duration, a stimulus duration, and a time out duration.

Inter-stimulus interval lists

Once the class becomes active, by registering an initial input from the user, a method then starts the ISI stopwatch procedure. The ISI is pseudo-randomized in the form of 'block randomization'. This means, a list of elements contain a range from 3 to 10 where each number represents the wait time in seconds and may only occur once in the list and every time a stimulus is active, an incrementation in the list is performed and the next element will be the amount of wait time for the next active stimulus. Currently, the application has three different list of blocks that can be chosen as the next list, when the previous one is completed. This solution creates somewhat stable amount of total stimuli while still simulating the effect of randomization.

Stimulus event

When the ISI duration is done, the stimulus stopwatch starts and a `stimulus` event is triggered and broadcasted to all listeners to that event. This is usefull for all other objects that has something to do with the active stimulus without the need of a direct reference of the time manager class.

If the application registers a following input from the user, the class then broadcasts either a `reaction time` event or a `false start` event, depending on the duration of the stimulus stopwatch. Once broadcasted, a new ISI duration starts and the procedure continues anew.

Time out event

If the time out timer reaches a duration more than 30 seconds, the stimulus stopwatch stops and a `time out` event is broadcasted. Signaling that it is a time out.

Stage duration event

The stopwatch methods continue, as long as the stage duration stopwatch has not reached 10 minutes or reached 10 minutes but a stimulus is still active. When the conditions are not met, a `game over` event is sent to signal the session is over. The check is only done after each active stimulus.

4.1.3 Stages

Two classes handle the stage procedure. One for the active stimulus, and a second one for the fish. Both classes are subscribed to events of the `TimeManager()` class. The `Stimulus()` class handles the visualization of the circles and needs to know when an active stimulus should appear, this is through the `stimulus` event and when a false start or time out should appear, and is through `false start` and `time out` event, respectively.

Fish and experience points

The `Fish` class handles the procedure of displaying the caught fish and is subscribed to the `reaction time` event. A method handles the check of the reaction time returned from the time manager class, and the displayed fish depends on the returned value.

There are currently three different stages, with each stage having its own type of fish. Each stage has four catchable fish which belong to one of the four different tiers of experience points, where the best tier yields the most experience points when consumed. Currently, the only way to obtain the best tier is through a random number generator which is called whenever the reaction time is within the first or second threshold limit. The first limit provides a slightly greater chance than the second limit, for the special fish. It is not possible to obtain the special fish in the third threshold limit, or if the RNG return value equals anything else than 1, and if that is true, the caught fish is then simply one of the three normal fish depending on the threshold limit. When a fish is caught, an event is broadcasted. One event for each fish type exists.

In addition to the two stage classes, a `Feedback` class was also implemented, which serve as textual feedback from the bear character whenever a condition is met; fish caught, false start, or time out. Thus, the class is subscribed to the `TimeManager` and `Fish` class with the corresponding events. The class itself simply handles a list of strings and output them accordingly whenever called.

4.1.4 Game over

The `GameOver` class handles all the statistics, including the amount of caught fish and the outcome metrics. The class is subscribed to both the time manager and fish class. The time manager class for displaying the outcome metrics, and the fish class for displaying the amount of caught fish. In addition, when the user clicks on the `Quit` button, the class performs a method call for saving the data before wiping the scene. The data is saved in Unity's `Playerprefs` file. Although only primitive variable types may be stored in the `playerprefs`, such as int, float, and strings, it was sufficient for the application.

4.1.5 Badges

There are currently seven badges in total, two badges for each stage, one for playing the stage and another one for catching the special fish, and a single badge which is awarded for reaching level 2. The `Badge` class handles the conditions for activating a badge. The class primarily consists of methods that simply checks certain conditions and whenever the conditions are met, a badge is unlocked. The class is subscribed to the `GameOver` class for checking the statistics. The badge class also utilize the `playerprefs`, for storing the information of whether a badge is unlocked or not.

Furthermore, the current implementation support easy and accessible integration of new stages, fish and badges. Since the three systems primarily consist of lists with their own variables and textures that just need to be replaced or added, extending the application in those aspects would not require much more work besides of creating new art assets and declaring conditions for whenever a badge should trigger.

4.1.6 Input and GUI

Because the game engine revolves around the concept of objects in the 3D space, thus all the objects in the application are treated as 3D objects as well. This includes input and GUI. Two cameras are implemented, a `main camera` for the stimulus and a `GUI camera` for the GUI. The GUI camera is `orthographic` and is rendered on top of the main camera. The GUI camera is an alternative solution for Unity's own GUI solution, including the `OnGUI()` method. Since the `OnGUI()` method can be costly in performance towards low-end machines due to the nature of multiple draw calls per frame.

For registering an input from a user, trigger boxes were set up and ray casting were performed by sending out a ray perpendicular to the camera view towards the scene. If a ray hit a trigger box, an event would then be broadcasted. All the classes that communicate with the `GUI` classes have their own check methods for checking the hit collider box. Although this imply a small overhead, since all checks are run each time a ray hits a collider, it is certainly much more clean and legible because only the relevant string checks are done in the relevant classes.

4.1.7 Audio

The `Audio` classes, one for the home screen and one for the stages, contain methods for playing the various sound effects by subscribing to the relevant classes, such as the `TimeManager` and `Fish` classes. This is simply done by having a list of audio files and play the right one once through the broadcasted events. Furthermore, the classes also handles the looping ambient background music which is set to play as soon as the application or stage is loaded.

4.2 Limitations

A major feature that had to be cut off early on in the implementation phase, was the friends system. This is primarily due to the complexity of networked applications, particularly for the desired functionalities, a somewhat dedicated server would be necessary. This is unfortunate in regards to gamification and the social aspect of the application, as that is often a major drive factor in game applications.

General limitations are the lack of subtle animations and feedback. Such as instead of static background images of the scenery, it was planned to have a somewhat more fluid and dynamic feeling as in moving clouds, small subtle particle effects flying around acting as leaves, or wave ripples would appear whenever an active stimulus occurs. This also counts for the bear character, both its animation and dialogue was planned to have a much greater depth than its current state.

4.3 Summary

With the implementation of the application which is powered by the game-engine Unity3D, some limitations were met. Primarily the exclusion of the friends system and the lack of rich feedback for environmental and user input, such as moving clouds, water ripples when a stimulus is active, subtle particle effects for input, and better animations for the bear character. The exclusion of the friends system means the application is a sole single player experience and thus may have a very different impact and game play experience than the would-be application.

This means the current implementation for the test sessions does not include the friends system, and would thus be on the specification list for future iterations. The next chapter, Chapter 5 describes the test setup along with results from the test sessions.

Chapter 5

Gamification Test

The gamification test investigates the intrinsic motivation of users compared between a regular PVT application and the implemented gamified PVT application. From the literature review, this is important since the regular PVT setting is considered impractical outside of laboratory environment both in form and design. This chapter first describes the hypotheses for the test experiment, followed by the methodology for the test sessions, and lastly, the test results are examined and evaluated.

5.1 Hypotheses

Hypothesis 1: Users will find a greater sense of perceived choice for the game application than the regular PVT.

Hypothesis 2: Users will find the game application more valuable and useful than the regular PVT.

Hypothesis 3: Users will find the game application more interesting and enjoyable than the regular PVT.

The hypotheses are constructed with the focus on the Intrinsic Motivation Inventory (IMI) [IMI, 2014], with three of the subscales as evaluation, the perceived choice, value / usefulness, and interest / enjoyment subscales, for measuring users intrinsic motivation.

5.2 Test Design

This section describes the test procedure, where each participant starts with one of the two versions, regular or gamified PVT, randomly even ordered. During each test session, observations are made through various methods, including in-game data logging, video recording of participants' facial expressions and the game screen. Once the participants have completed a test session, they are evaluated with a questionnaire regarding their intrinsic motivation towards the applications, and in addition, an informal interview is also conducted, regarding their experience and thoughts about the applications.

5.2.1 Two versions of the PVT application

Participants are supposed to perform a test session for both a regular PVT application and a gamified PVT application. Creating a regular PVT application is done by stripping off all game related elements in the implemented application, leaving the application with only the essential design criterias, found in Basner and Dinges proposed framework.

A stage in each version lasts for 10 minutes and when the duration is over, the application shows the performance screen with the amount of fish caught or the outcome metrics. This ends the participant's test session for that application version as well. Both versions have the same ISI block randomization, and same display time for user input. Visual feedback for the regular PVT application shows the reaction time in milliseconds, instead of a fish. Furthermore, no audio exists in the regular PVT application. Figure 5.1 shows screenshots from the regular PVT and game version side by side.

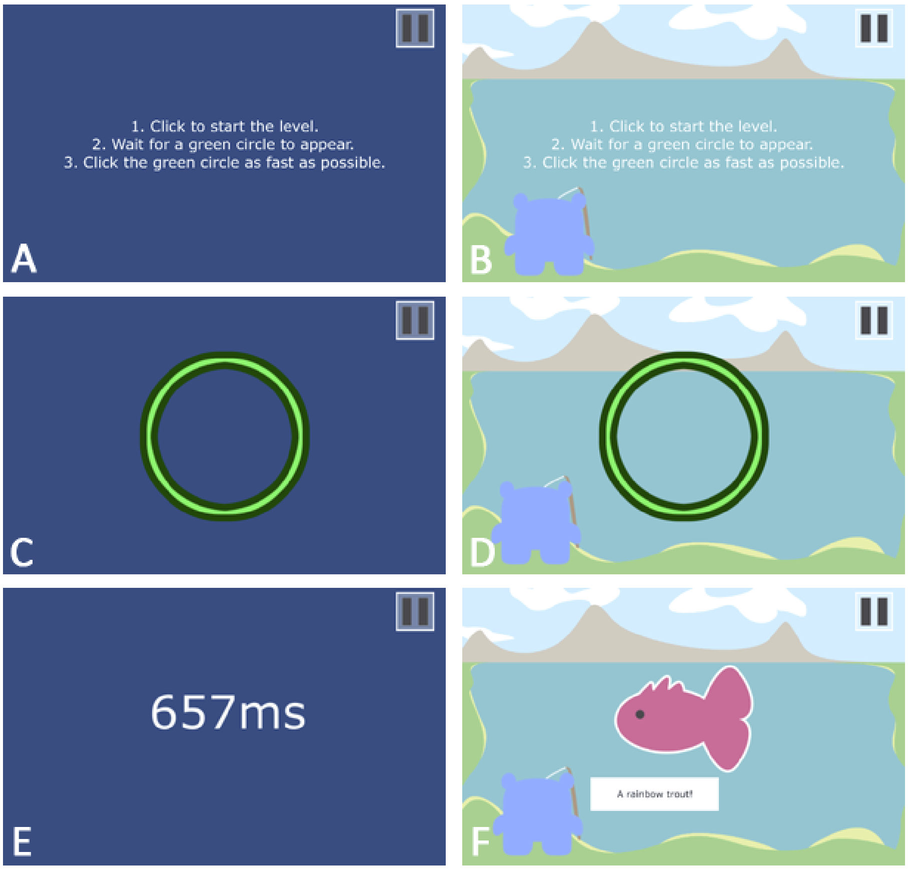

Figure 5.1: *(A) shows the introduction text box for the regular PVT version, and (B) shows the introduction for the game application. After the participant has clicked once on the screen, the PVT session starts. (C) and (D) shows the appearing active stimulus as a green circle for the regular PVT and game version, respectively. Once the system recognize a valid input from the participant when a stimulus is active, the reaction time or a caught fish is shown. (E) shows the feedback for the regular PVT, and (F) shows the feedback for the game application. It should be noted that when participants try the game application, they are first presented with the home screen where they can choose which stage they wish to play or explore some of the other features. This is not the case for the regular PVT application.*

5.2.2 In-game data logging

For each test session, in-game data is logged to create statistics of the proposed outcome metrics along with the amount of caught fish. In addition, this is also useful for evaluating the participants' performance over time during the test sessions.

Three reaction time intervals were decided, 150-319ms, 320-499ms, and 500+ms. The lower limit is inspired by the human processor model from the literature review which suggest that a reaction time of around 150ms or less is very unlikely and that average reaction time should approximately be around 250ms, however, for the sake of gameplay fairness, the upper limit of the first interval was further arbitrarily increased to 319ms. The second interval is for creating more reward intervals of caught fish and is simply a continuation from the first interval's upper limit, to right before lapse indication, which the literature suggested as 500ms or more.

5.2.3 Video recording

For each test session, with permission, video recording is logged. Recordings are done by an integrated webcam, for facial expressions, and a third party recording application, for the game screen. The webcam recording can be useful to examine facial expressions during the test sessions, for any indications of changes in intrinsic motivation. And the game screen recording can be useful to examine any usability or technical issues that the participants' might have with the application, which may also indirectly have an impact on the intrinsic motivation.

5.2.4 Questionnaire

After each test session, the participants' are evaluated through a questionnaire. See Appendix B for the full questionnaire, and the consent form which is signed before the start of the test session. The question utilizes the setup of the Intrinsic Motivation Inventory with the *interest / enjoyment*, *perceived choice*, and *value / usefulness*, as subscales for weighting the intrinsic motivation [IMI, 2014].

First, the questionnaire is concerned about the participants' demographics, which is gender and age. Next, the questionnaire asks the participants' about prior experience with similar applications that they have just tried. If they do have prior experience, the questionnaire continue on with asking their *interest / enjoyment* and *value / usefulness* of those applications, by letting them rate a set of items taken from the IMI in the form of a Likert scale, ranging from 1 to 7, where 1 is not true and 7 is very true to the statement.

The questionnaire then proceeds on with asking the participants about their experience with digital games, including their favorite type of genres and how many hours per day they spend on digital games. This is useful for gaining an overview of how experienced the participants are in regards to game feedback and mechanics for various game genres, and thus may have an impact on the onboarding experience.

Lastly, the participants are asked to rate their *interest / enjoyment*, *perceived choice*, and *value /*

usefulness from a set of items taken from the IMI, in the form of a Likert scale, ranging from 1 to 7, where 1 is not true and 7 is very true to the statement. Each subscale has a set of items, and the scoring of each subscale is the average of the items. Some items are negatively phrased, and thus must first be score reversed by subtracting the rate from 8.

As a closure to the test session, the participants are asked a few informal questions regarding the gameplay experience and their initial thoughts of what worked and what did not work, and possible solutions for such issues. The questions asked are broad in topic with follow-up questions if needed for deeper clarity. The topics asked are as follow;

- Did you notice any game elements / mechanics that worked well and why do you think they worked well?
- Did you notice any game elements / mechanics that did not work well and how can they be improved?
- What is your experience with the game setting in general, character, fishing after fish, different fish and levels, badges and experience points, etc. ?
- What is your experience with the audiovisual setting?

5.3 Results

Two test periods were conducted, one session in PrivatHospitalet Skørping, which is a private hospital for special treatment such as sleep disorders, and a second test session on the University campus for Medialogy students. Four patients in total were acquired to try the applications in Skørping, and a total of 13 students participated to try the applications. The test sessions were conducted in the early to mid afternoon, and according to the interview with Jan Ovesen (see Appendix A), under normal circumstances would be the optimal time for performing PVT sessions since the hours of wakefulness have only been around 8-10 hours and that people should perform normally at that time. Additionally, the students reported they assumedly were not suffering any sleep conditions.

Participants	**N=4**
Gender	Male (4)
Age	42-75
Prior PVT exp.	None
Prior digital games exp.	Yes (2)
Hours/day on digital games	1-4 (2)
Preferred type of games	Sudoku, crosswords, platform, adventure

Table 5.1: *Demographics for the patients answered in the questionnaire.*

Table 5.1 shows the demographics of the patients. The participated patients were elderly people with no apparent experience with prior PVT applications. Two of the patients played digital games regularly while the other two patients did not play digital games at all.

Participants	N=13
Gender	Male (10), Female (3)
Age	22-31
Prior PVT exp.	Yes (3)
Prior digital games exp.	Yes
Hours/day on digital games	1-4
Preferred type of games	RPG, FPS, MOBA, adventure, action, puzzle, strategy

Table 5.2: *Demographics for the students answered in the questionnaire.*

Table 5.2 shows the demographics of the students. The participated students were in the younger age group than the patients, however, only three of the students had prior experience with PVT appplications. On the other hand, all the students were very familiar with digital games and many of them played a large variation of game genres.

5.3.1 Performance

During gameplay, the applications logged the participants' performance in regards to the outcome metrics along with the mean RT over time. Table 5.3 shows the patients' mean outcome metrics and Table 5.4 shows the mean reaction time, for during the regular PVT and game session. Figure 5.2 and Figure 5.3 shows a visual representation of the mean RT over time for the patients.

Participants (N=4)	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
150-319ms	5.000	5.000	11.888	12.000
320-499ms	62.750	43.500	13.102	21.626
500+ms	17.250	37.000	19.485	26.608
Mean RT (seconds)	0.432	0.480	0.098	0.175
Median RT (seconds)	0.423	0.473	0.101	0.089
Visual stimuli	85.000	85.500	5.416	1.915
Lapses	17.250	37.000	19.485	26.608
Lapse probability (%)	20.443	43.430	23.428	31.365
False starts	6.000	2.750	9.416	3.202
Performance score	0.750	0.543	0.312	0.286

Table 5.3: *Mean outcome metrics of the patients' performance.*

Table 5.3 shows that the majority of the valid reaction times from the patients are in the 320-499ms interval for the number of valid stimuli with a mean of 62.750 (SD=13.102) for the regular

PVT and a mean of 43.500 (SD=21.626) for the game application. However, the table also indicates that the patients experienced many lapses, with a mean of 17.250 (SD=19.485) for the regular PVT and 37.000 (SD=26.608) for the game application. This yields a lapse probability of 20.443% (SD=23.428%) and 43.430% (SD=31.365%) for the regular PVT and game application, respectively.

Timestamp (minutes)	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
0-1	0.521	0.514	0.119	0.089
1-2	0.404	0.404	0.141	0.114
2-3	0.436	0.428	0.105	0.113
3-4	0.410	0.423	0.090	0.110
4-5	0.436	0.419	0.110	0.094
5-6	0.443	0.432	0.080	0.070
6-7	0.408	0.443	0.098	0.092
7-8	0.416	0.446	0.085	0.059
8-9	0.455	0.440	0.140	0.097
9-10	0.531	0.465	0.159	0.110

Table 5.4: *Patients' mean RT over time for during the regular PVT and game session, N=4.*

Table 5.4 provides the patients' mean reaction time over time during the test sessions. However, it should be noted that through the video recording, the participants spent the first minute with onboarding experience which is also suggested by the table. Because the mean reaction time of the 0-1 minute duration is relatively high compared to the other duration intervals and quickly falls when duration 1-2 minute is reached, meaning the participant has gotten used to the gameplay. Since the hypotheses are centered around users' intrinsic motivation and less about their actual performance, the data points of 0-1 minute duration were not discarded as they act as visual indication for onboarding issues that need to be handled. Thus, Table 5.4 indicates that the optimal performance is right at the start, namely the interval duration 1-2 minute, with a mean of 0.404s (SD=0.141s) and 0.404s (SD=0.114s) for regular PVT and game application.

Furthermore, the results of Table 5.4 suggest that the reaction time is slowed after the initial minute duration, and at minute duration 9-10, the mean is 0.531s (SD=0.159s) and 0.465s (SD=0.110s) which translates to a performance drop of approximately 127ms for the regular PVT and 61ms for the game application, over a duration of 9 minutes. During the 9-10 minute period, the table indicates that the patients experience 'small energy boosts', approximately around 3-4 minute and 6-7 minute, with a small performance boost as a result. However, the energy boosts seem to only last for a very short amount of time as the reaction time quickly drops again.

Table 5.5 shows the students' outcome metrics and Table 5.6 shows the mean reaction time, for during the regular PVT and game session. Figure 5.4 and Figure 5.5 shows a visual representation of the mean RT over time for the students.

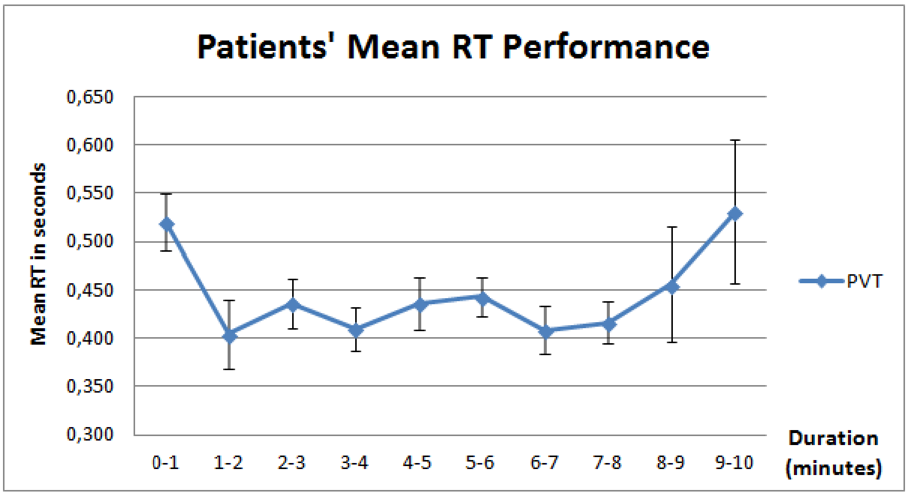

Figure 5.2: *Visual representation of the patients' mean reaction time for during the regular PVT session. The error bars represent the standard error of the mean.*

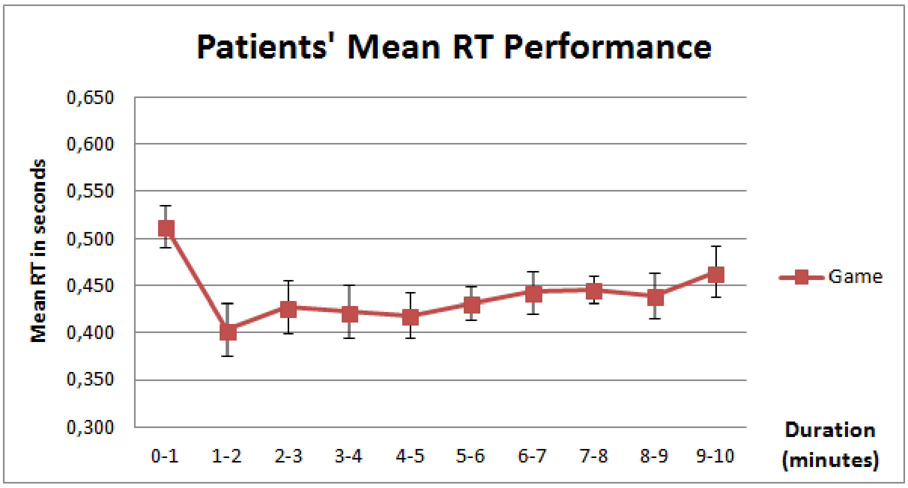

Figure 5.3: *Visual representation of the patients' mean reaction time for during the game session. The error bars represent the standard error of the mean.*

Likewise with the performance from the patients, Table 5.5 shows that the majority of the valid reaction times from the students are in the 320-499ms interval for the number of valid stimuli with a mean of 65.250 (SD=9.692) for the regular PVT and a mean of 70.375 (SD=6.718) for the game application. Additionally, the table also indicates that the students did not experience as many lapses as the patients, with a mean of 7.875 (SD=10.467) for the regular PVT and 5.750 (SD=3.991) for the game application. This yields a lapse probability of 9.175% (SD=12.339%) and 6.553% (SD=4.553%) for the regular PVT and game application, respectively.

Table 5.6 provides the students' mean reaction time over time during the test sessions. The table provides similar patterns as with the patients. Again, likewise with the test sessions of the patients, the first interval duration 0-1 minute, is used for the onboarding experience. Table 5.4 indicates that the optimal performance for the students is also right at the interval duration 1-2 minute, with a mean of 0.361s (SD=0.069s) and 0.349s (SD=0.062s) for regular PVT and game application.

Participants (N=13)	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
150-319ms	13.625	10.875	9.680	8.097
320-499ms	65.250	70.375	9.692	6.718
500+ms	7.875	5.750	10.467	3.991
Mean RT (seconds)	0.385	0.381	0.083	0.045
Median RT (seconds)	0.377	0.373	0.044	0.023
Visual stimuli	86.750	87.000	1.389	2.204
Lapses	7.875	5.750	10.467	3.991
Lapse probability (%)	9.175	6.553	12.339	4.553
False starts	2.750	3.000	1.389	3.207
Performance score	0.881	0.903	0.125	0.031

Table 5.5: *Mean outcome metrics of the students' performance.*

Timestamp (minutes)	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
0-1	0.557	0.474	0.546	0.331
1-2	0.361	0.349	0.069	0.062
2-3	0.364	0.361	0.066	0.043
3-4	0.358	0.363	0.077	0.047
4-5	0.366	0.355	0.046	0.063
5-6	0.371	0.366	0.077	0.072
6-7	0.367	0.375	0.061	0.029
7-8	0.413	0.396	0.186	0.059
8-9	0.386	0.397	0.053	0.066
9-10	0.387	0.388	0.043	0.054

Table 5.6: *Students' mean RT over time for during the regular PVT and game session, N=13.*

Further similarities are also suggested through the small duration of energy boosts, as the results of Table 5.6 indicate that the same interval durations are at 3-4 minute and 6-7 minute, however with an additional small performance boost towards the end of 8-9 minute and 9-10 minute interval. Over the 9-10 minute duration, the performance drops with approximately 26ms for regular PVT and 39ms for game application, with a mean of 0.387s (SD=0.043s) and 0.388s (SD=0.054s).

5.3.2 Intrinsic motivation rating

After each test session, the participants were handed the intrinsic motivation questionnaire to fill out. Table 5.7 shows the ratings from the patients, and Table 5.8 shows the ratings from the students. Figure 5.6 and Figure 5.7 show a visual representation of the three subscale ratings from

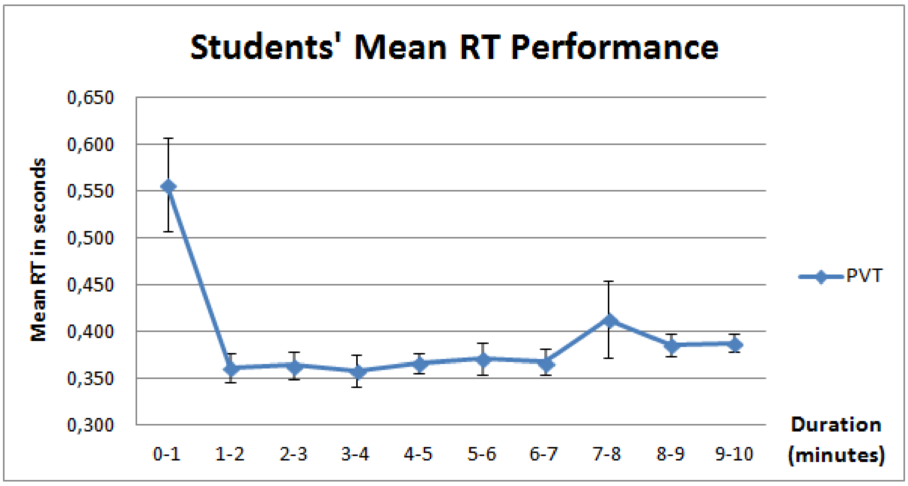

Figure 5.4: *Visual representation of the students' mean reaction time for during the regular PVT session. The error bars represent the standard error of the mean.*

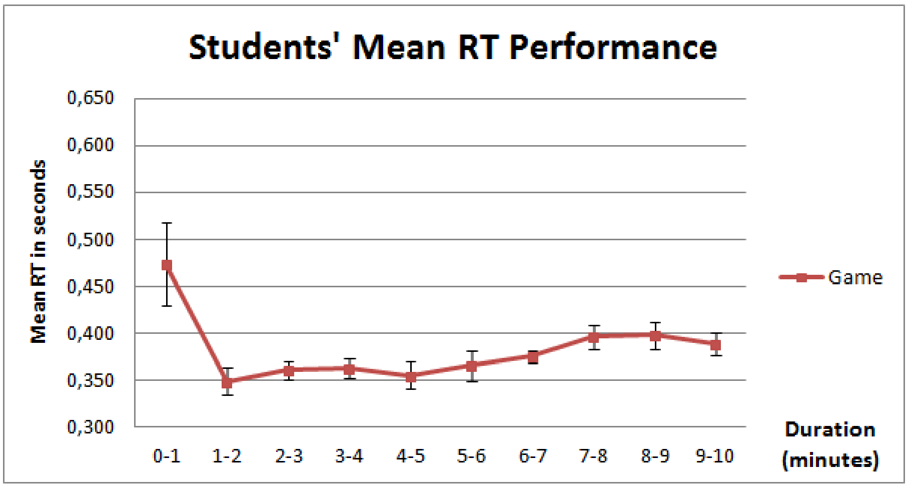

Figure 5.5: *Visual representation of the students' mean reaction time for during the game session. The error bars represent the standard error of the mean.*

the patients and students, respectively.

Participants, N=4	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
Perceived minutes spent	8.000	7.750	2.828	5.260
Interest / enjoyment	3.813	3.500	3.929	5.549
Value / usefulness	3.389	3.250	2.626	3.027
Perceived choice	4.250	4.719	2.880	4.313

Table 5.7: *Patients' intrinsic motivation rating and perceived minutes spent on each test session.*

Table 5.7 indicates that the patients perceived the duration of the regular PVT to be longer than the game application, with a mean of 8.00 minutes (SD=2.828) and 7.75 minutes (SD=5.260), respectively. The table also shows the patients' mean rating for the interest and enjoyment subscale is 3.813 (SD=3.929) for regular PVT and 3.500 (SD=5.549) for game application. Additionally, the value and usefulness subscale was rated with a mean of 3.389 (SD=2.626) and 3.250 (SD=3.027), respectively. Lastly, the perceived choice was rated relatively high for both PVT and game application, the perceived choice of the game application was rated with a mean of 4.719 (SD=4.313) and for the regular PVT, a mean of 4.250 (SD=2.880).

Participants, N=13	Mean, PVT	Mean, Game	SD (95%), PVT	SD (95%), Game
Perceived minutes spent	9.692	10.231	6.239	5.897
Interest / enjoyment	2.067	2.529	1.333	1.659
Value / usefulness	3.325	2.889	1.424	1.766
Perceived choice	4.212	4.548	3.267	2.563

Table 5.8: *Students' intrinsic motivation rating and perceived minutes spent on each test session.*

In contrast, Table 5.8 shows that the students perceived the duration of the regular PVT to be shorter than the game application, with a mean of 9.692 minutes (SD=6.239) and 10.231 minutes (SD=5.897), respectively. The table also shows the students' rating of interest and enjoyment with a mean rating of 2.067 (SD=1.333) for regular PVT and 2.529 (SD=1.659) for game application. Additionally, their rating of value and usefulness, with a mean rating of 3.325 (SD=1.424) for the regular PVT and 2.889 (SD=1.766) for the game application. However, of the three students that had prior PVT experience, the mean ratings of interest / enjoyment and value / usefulness were rated higher for the prior experience than both the regular PVT and game application, as shown in Figure 5.7. Lastly, likewise with the patients, while the perceived choice was rated relatively high for both PVT and game application, the perceived choice of the game application received a higher rating than the regular PVT, with a mean of 4.548 (SD=2.563) compared to 4.212 (SD=3.267).

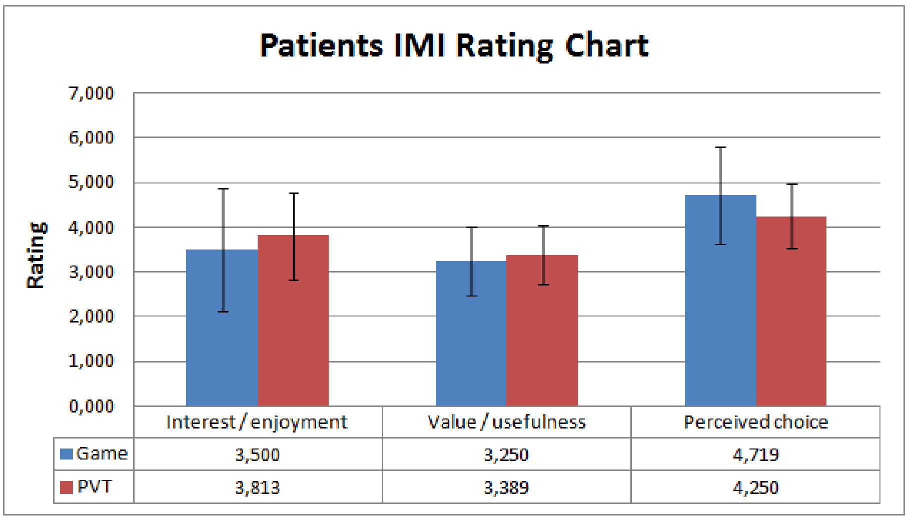

Figure 5.6: *Visual representation of the patients' intrinsic motivation rating for both regular PVT and game session. The error bars represent the standard error of the mean.*

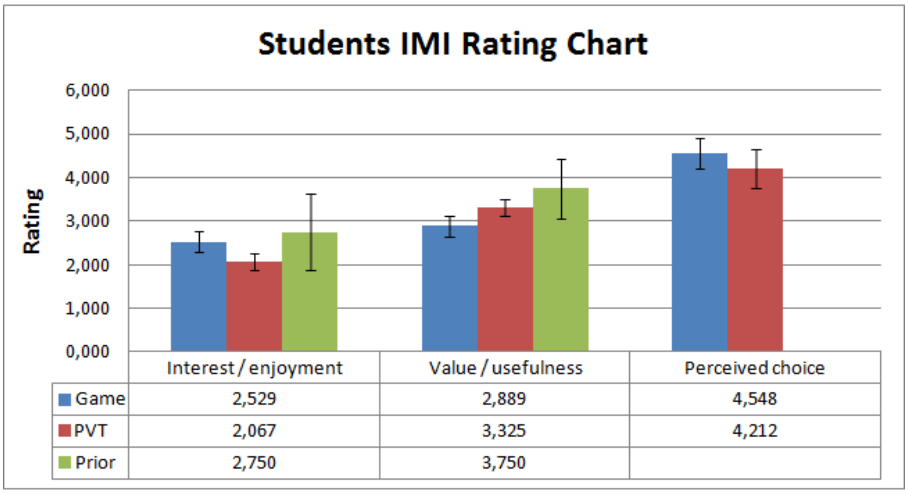

Figure 5.7: *Visual representation of the students' intrinsic motivation rating for both regular PVT and game session. The error bars represent the standard error of the mean.*

5.3.3 Hypothesis testing

Assuming the following hypotheses for testing the statistical significance of the provided data from the questionnaire ratings.

- *Null Hypothesis 1: Users will not find a greater sense of perceived choice for the game application than the regular PVT.*
- *Alternative Hypothesis 1: Users will find a greater sense of perceived choice for the game application than the regular PVT.*
- *Null Hypothesis 2: Users will not find the game application more valuable and useful than the regular PVT.*
- *Alternative Hypothesis 2: Users will find the game application more valuable and useful than the regular PVT.*
- *Null Hypothesis 3: Users will not find the game application more interesting and enjoyable than the regular PVT.*
- *Alternative Hypothesis 3: Users will find the game application more interesting and enjoyable than the regular PVT.*

The performed hypothesis test uses a paired Student's t-test, because the data consist of two samples from each participant. One sample for the regular PVT, and another sample for the game application, where the matching groups are the three subscales taken from the IMI questionnaire. Furthermore a chosen significance level of $0.01 < p < 0.05$ must be met in order to reject the null hypothesis.

Starting with the patients' perceived choice rating, where the mean for the PVT is 4.212 (SD=3.267) and the mean for the game application is 4.719 (SD=4.313), with paired $t(3) = 0.5798$, $p = 0.6027$ for two-tailed. The value and usefulness rating with a mean of 3.389 (SD=2.626) and 3.250 (SD=3.027), with $t(3) = 0.2165$, $p = 0.8425$. Lastly, the interest and enjoyment rating from the patients, with a mean of 3.813 (SD=3.929) and 3.500 (SD=5.549), with $t(3)= 0.5155$, $p = 0.6418$.

Thus, with the results from the hypothesis testing of the patients' rating, all three hypotheses are rejected and the null hypotheses are accepted for the patients, since all the reported p-values have no statistical significance.

Next, the paired Student's t-test is performed on the ratings from the participated students. Starting with the perceived choice, where the mean is 4.212 (SD=3.267) and 4.548 (SD=2.563) for regular PVT and game application, respectively, yields $t(12)= 0.8681$, $p = 0.4024$ two-tailed. For the value and usefulness, the mean is 3.325 (SD=1.424) and 2.889 (SD=1.766), with $t(12)= 1.4674$, $p = 0.1680$. Lastly, the ratings of interest and enjoyment with a mean of 2.529 (SD=1.659) and 2.067 (SD=1.333), with $t(12)= 2.4896$, $p = 0.0285$.

With the results from the hypothesis testing of the students' rating, two of the hypotheses are rejected, namely Hypothesis 1 and 2, which involve the rating of perceived choice and value / usefulness. Only Hypothesis 3 is accepted due to a statistical significance and thus the null hypothesis is rejected, which also means the students seem to be interested / enjoyed the game application more than the regular PVT.

5.3.4 Participant comments

A compilations of the comments are taken from the informal interviews of both patients and students. Figure 5.8 shows a hierarchy mind-map of the frequent comments with overlapping topics as subgroup headers. Eight subgroups are constructed from the yielded comments, with focus on game content and game feedback as main topics. The subgroups cover a large portion of issues that the game application might have, with possible solutions in mind.

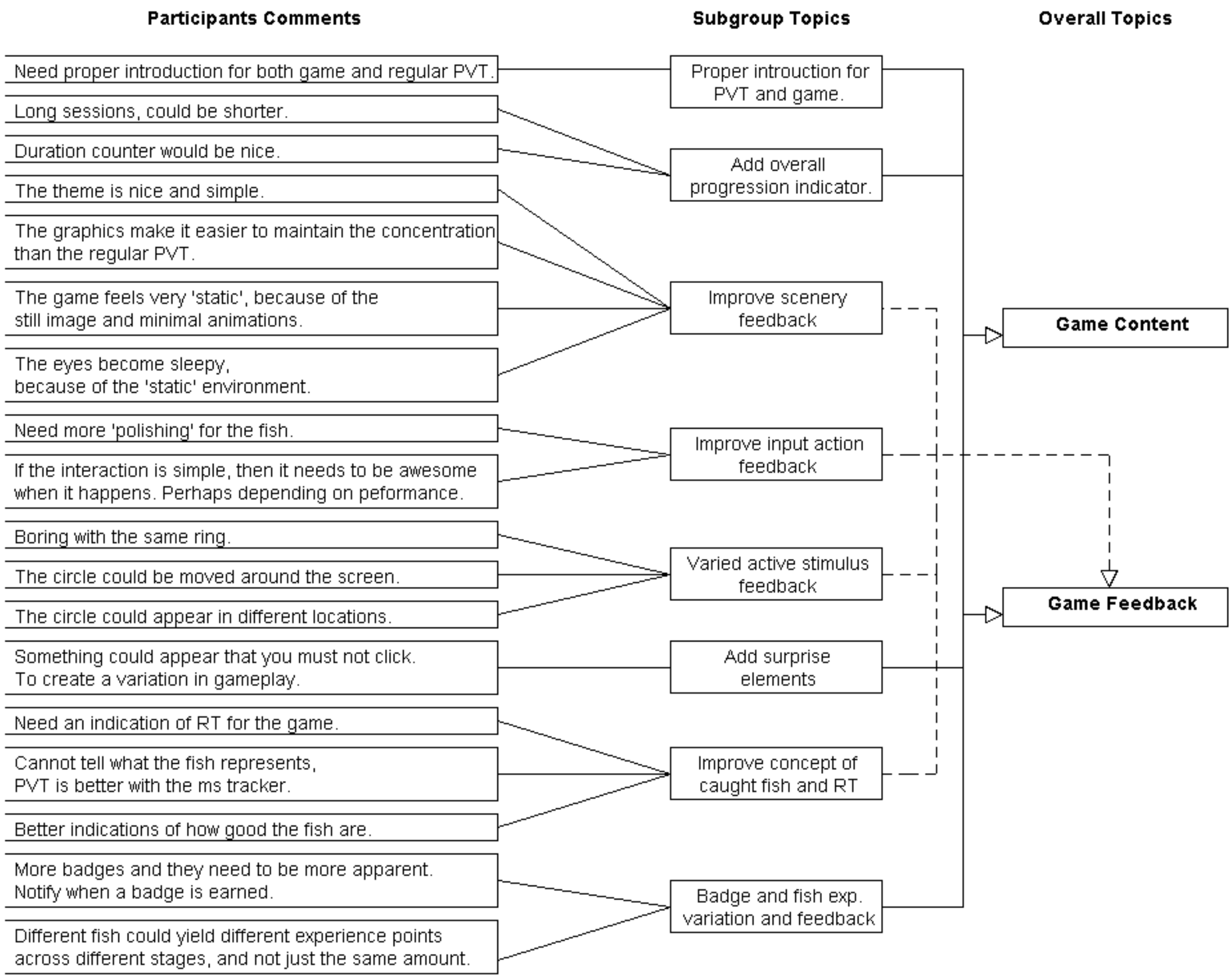

Figure 5.8: *A hierachy mind-map of the participants' frequent comments grouped into topics.*

5.4 Summary

With the test results charted, the results indicate that there were no significant difference for the preference between game application and regular PVT with the patients, while there was a large enough significant difference for the students' interest and enjoyment. Furthermore, with informal interviews as follow-up to the questionnaire, a hiearchy mind-map of the frequent comments from the participants was created, to gain an overview of the good and bad aspects of the application. This yielded eight different subcategories with either game content or game feedback as main focus.

Thus, the next chapter, Chapter 6 evaluates the test results and comments along with discussing possible solutions for existing issues of the application for future work.

Chapter 6

Test Evaluation

The results from the students, found in Table 5.8, seem to support one of the three constructed hypotheses, namely the hypothesis regarding the interest and enjoyment factor, however, the results from the patients, found in Table 5.8, do not indicate support for any of the constructed hypotheses. However, although the students rated the game application more interesting than the regular PVT, both scores are relatively placed on the lower-end of the scale, which means they might not have particularly enjoyed the test sessions at all. Furthermore, both user groups seemed to value or find the regular PVT more useful than the game application, which indicates the game application failed to convey the importance and relevance of sleepiness assessment. Additionally, although only three of all the participants had prior experience with PVT settings, they rated the prior experience higher than both the regular PVT and game application, in regards to enjoyment and usefulness, as shown in Figure 5.7.

However, the reported results from the ratings only provide numerical indications of users' intrinsic motivation and not so much about the reasonings. Fortunately, feedback comments and suggestions from the informal interviews provide the subjective answers regarding the user experience and intrinsic motivation towards the game application, as shown in Figure 5.8. Thus, this chapter discusses the frequent comments and feedback provided by the participants with subcategories as common denominator. This also means, the following sections discuss the various topics as a mean of reflection for the test results from the questionnaire ratings.

6.1 Lack of proper introductory system

Starting with the first user comments, it becomes apparent when looking at Table 5.4 and Table 5.6 that the participants were struggling with the onboarding experience, althought both applications included a brief tutorial with instructions in the form of a text box. The user comments received address this issue, where one user respond with, *"...at the beginning, it was a bit confusing for what to do, because the purpose of responding as fast as possible wasn't clear enough. But after a few tries, it became trivial"*. Another participant brings up the uncertainty of where to click on the screen for input, *"...I thought you had to click on the green outline of the circle in order to register an input, only to discover after a few tries that you could click on the center of the circle as well"*.

The lack of emphasis on the notation for fast reaction time as possible, and possible interactive areas on the screen, are both very important factors that the tutorial is missing or has not emphasized enough. This means, the missing components will have a negative impact on the onboarding experience and potentially turn away new users that do not have the patience for trial-and-error approach.

A possible solution would be expanding the current tutorial into a small sequence of task oriented gameplay, where the first few instances of the stimuli list are dedicated to onboarding new users. Meaning, if the system recognize a new user and the user selects the very first stage, the system would then ask the user if he wishes to do a small tutorial. If the user then accepts the offer, the stage could initiate small animations with helpful texts and images which show how to play the stage with proper user input. And once the animations are done, the stage can then begin the real PVT session. The tutorial sequence could also be listed as a separate stage or grouped into stages, so that users can visit the tutorial stages any time and replay specific game mechanics.

6.2 Overall progression indication

The current implementation both for the regular and game versions do not include a visible progression indicator, due to no guidelines suggested from Basner and Dinges. However, a few of the participants requested some form of indication for progression, particularly from the students. With responds such as, *"...it is always nice to see how far you are in the levels..."* and *"...since you just do the same over and over again, it would be great with a form of indication for progression"*. This is further strengthen by the notion of the students were reported as experienced gamers, and since many games have some sort of progression indication and often in the form of a timer or score, it became apparent for the students that the application was missing such an indication.

The application do have a duration timer for the stages, but is however not transparent for the users. Further more, this also applies to the amount of caught fish which is not displayed until the very end at the gameover screen. Simple solutions would be to reveal such variables and make them transparent for the users, to provide a sense of progression. Meaning when users play a stage, there would be a visible count down timer for the duration and the caught fish could be displayed as a pile of fish, beside the bear character. Taking a humoristic approach, the pile of fish could then keep growing as more fish are caught, and if the user performs well, the pile of fish would end up as one giant pile covering a large chunk of the screen.

Additionally, by making the count down timer transparent, the application could also direct the experience to a more serious note of one's sleepiness state. Meaning, the application could add emphasis on the performance during the 10 minute duration, and that it is supposed to represent the likelihood of sleep deprivation. By doing so, users might perceive the application as more useful than it currently is. However, since the duration was the same throughout all stages, it is uncertain whether the full 10 minutes duration has a significant impact on the intrinsic motivation, which would require additional test iterations for validation.

6.3 Scenery feedback

The scenery and background simply consist of a still image and thus do not have any kind of feedback towards user interaction or 'dynamic and lively' feeling. Unfortunately, this was also noted by the participants with comments such as, *"...game feels very static, because of the still image and minimal animations..."* and *"...the eyes become sleepy"*. However, the issue is already noted and was a part of the limitations in the implementation process. Thus, ideal sceneries would contain small repeating animations such as clouds moving across the background, tree leaves moving and particle effects imitating flying leaves carried by the wind, leaves and water ripples moving across the river, and so on. Essentially mimicking a realistic landscape. Furthermore, keeping the tone as a light-hearted humoristic setting, a set of unusual objects could appear from time to time as well, such as an airplane moving across the sky, a friendly bear could appear at one of the screen sides, a duck family swimming across the river at the horizon and so on, to further create the sensation of non-static environment and thus possibly have an impact on the interest and enjoyment factor.

6.4 Input action feedback

Likewise with the scenery limitations, the action feedback is also very sparse and restricted. Currently all caught fish feedback is the same regardless of reaction time, which has the unfortunate effect of saturating the supposed excitement whenever a 'big' or 'special' fish is caught. This is emphasized by a comment from a participant, *"...if the interaction is simple, then it needs to be awesome when it happens...and perhaps let it depend on performance"*. This means, each fish tier could have their own set of feedback animations, so that when users catch a big or special fish, a rotating star effect behind the fish or similar and a large amount of particle effects around the fish would spawn, while catching a small fish results in a smaller rotating star effect and less particle effects.

6.5 Active stimulus variation

The idea of a circle appearing when a stimulus is active, is supposed to simulate the effect of water ripples when a fish takes the bait. The current implementation lacks the animations and thus, the result is a static circle that only wobbles a little and miss all the additional ripples altogether. This was surely noted by the patients and many of the students, as they found it *"...boring with the same ring"*. Another issue that was brought up by the participants was, *"...the circle could be moved to or appear in different locations of the screen"*. Meaning, they found it boring and to some degree too easy, that the circle always appeared at the same exact place on the screen.

A possible solution for both issues could be to add a 'bait indicator' on top of the water ripples. This means, the bear character would first do an animation creating the illusion of a fishing line being thrown, and then the bait indicator would appear in different locations and have an idle animation that floats a bit up and down. When an active stimulus appears, the bait indicator would then wobble wildly while water ripples appear as well. And when a user input is registered, the caught fish would appear and the process starts anew.

Expanding on the concept, users could be allowed to customise and choose among different fishing equipment, by purchasing them from an in-game shop with the fish caught as currency, for keeping the simplicity and reengagement loop. Additionally, the customization could also apply to the bear character with various clothes and accessories, further strengthen the motivation to perform the sessions.

6.6 Concept of caught fish and RT

An issue that became apparent during the test sessions was the lack of understanding the different fish tiers, as almost every of the participants commented, *"...it is very difficult to tell what the fish represents...because you only see a fish icon with no extra information"*. Although before the actual stage, users could see all the catchable fish for that specific stage, in the stage selection menu. However, admittedly, the fish information provided in the stage selection menu could be much more refined and legible, since the information only states the names of the fish with no indications of how valuable each fish are. This led to many notions such as, *"...PVT is better with the ms tracker...and needs an indication of RT for the game"*. Furthermore, one of the patients that had experience with digital games even commented that *"...I liked the PVT more because it suddenly becomes a competition for yourself"*.

An apparent solution would be to display the reaction time when a fish is caught and thereby keep the focus on the PVT session and precision of the input feedback. However, as with any other kind of HUD, the RT tracker has the possiblity to break the immersion of this fantasy setting that users embark themselves on a fishing trip with this bear character. An alternative solution would be to make the fishing information clearer in the stage selection menu, with text or increasing visual effect for the different fish tiers, in combination with the actual fish feedback when caught as discussed earlier.

Taking a different approach towards the reaction time, which currently translates directly to a specific fish tier, would be akin to the earlier discussed concept of customisable equipment. The concept could be that the fishing rod or its components appear to be 'upgradeable' which allows the user to catch bigger or 'better' fish, and thereby only rely the caught fish on the tier of the fishing rod and disconnect the link between reaction time and fish tier entirely. This would provide an additional sensation of progress besides the current experience points system, and allow all users to catch the same fish despite their sleepiness state, while the data logging would be unaffected.

6.7 Surprise elements

Some of the participants, particularly the students, requested that *"...something could appear that is different or that you must not click on, to create a varied gameplay, since the gamplay is very repetitive"*. Adding on with the fact that the current application is solely a single-player experience and that the friend system was omitted, leaving the stages as the only element for varied gameplay experience, it unfortunately strengthen the monotonous and repetitive feeling of the PVT setting.

In addition to the friend system, the feature could be expanded upon in the sense that sometimes during a stage, other bears, possibly from the user's friend list distinguished with different colors or clothes, could at times appear with similar intention of fishing after fish. The newly appeared bear will only be computer controlled character and thus the actual friend does not have to be playing at that time. When such characters appear, additional active stimuli will appear as well, acting as 'fake' stimuli and thus the user is to avoid them by not clicking on the area of the fake stimulus. After some duration, the other bear characters will disappear again by moving out of the screen. The concept adds the illusion of social aspect, and real life bears fishing after fish together is not uncommon either, particularly at spawning seasons with the abundance of fish swimming into the shallow water of rivers.

6.8 Badge and fish experience points variation

Lastly, the topics that the participants commented on revolved around the badge and fish experience points. For the badges, they requested that a notification should appear when a badge is earned, as currently no feedback is present when users earn a badge. The notification could be a simple pop-up text box with the corresponding badge icon, telling the user that the badge was just unlocked through the accomplished task.

Although the participants only examined the experience points system for a brief moment, comments were noted regarding, *"...different fish could yield different experience points, across different stages"*. The amount of experience points should then scale appropriately with the minimum requirements for playing different stages. This means, the fish should reward a balanced amount of experience points when consumed so that users do not immediately unlocks all the stages already after the first or second game session. Likewise, nor should users spend too many game sessions on the same stage just to unlock the next stage.

6.9 Summary

This chapter has discussed the frequent topics that the participants commented during the interviews.

- **Proper introduction**. It was requested that both the game application and regular PVT were missing proper introductory procedure. The solution would be to expand the current introduction to a more detailed and refined procedure, such as separated stages for tutorial purposes.
- **Progression indication**. Many of the participants thought it would be convenient with any indications of progression during a session. This could be fixed by making the stage duration timer more transparent in the form of a visible count down, while emphasis could be put on that the duration represents the seriousness of sleep deprivation.

- **Scenery feedback**. The effect of still image and lack of any animations as background scenery were noted by the participants and commented that they found it boring as it is. This would be remedied by applying the intended subtle animations for various parts of the sceneries, such as moving clouds or flying leaves across the screen.
- **Input action feedback**. As like with the sceneries, the participants commented that the input action feedback for catching fish was very dull and could be improved by applying more 'juiciness' for whenever a fish is caught.
- **Active stimulus feedback**. Regarding the stimuli, many of the participants suggested that the active stimulus could appear in different locations or move around a bit, to make the gameplay less monotonous.
- **Surprise elements**. In order to create a varied gameplay experience, it was also suggested that some kind of stimulus could appear that the user must avoid clicking on. This could be in the form of another bear appearing as computer controlled, with 'fake' stimuli appearing to distract the user.
- **Fish and RT tracker**. Many of the participants commented that they missed the link between caught fish and reaction time, meaning they did not understand what the different fish represented in regards to the performance. A possible solution would thus be to include the reaction time tracker and display it to the user, while an alternative solution would be to emphasize the meaning of the different fish tiers before the start of the stage, possibly at the stage selection menu.
- **Badge and XP feedback**. The lack of any notification for when a badge is earned were noted by some of the participants and also that the different fish tiers yield the same amount of experience points across the different stages.

With the topics covered, suggesting that the application still has many design considerations that need to be addressed and fixed for future iterations, in order to increase users' intrinsic motivation for using the application. Thus, the next chapter, Chapter 7 concludes the project with a summarisation of the process.

Chapter 7

Conclusion

A PVT application was implemented containing various aspects of gamification. The gamification aspects revolve around the concept of embarking on a fishing trip with a virtual bear avatar, where the incorporated gamification features, such as experience points and badge system, along with a point system in the form of caught fish, are supposedly to keep users motivated and interested in the application. Thus, two hypothesis testing sessions were conducted, with two different user groups. One group consisted of patients with sleep disorder and another group consisted of university students with supposedly no sleep disorder. The two groups were asked to try the implemented application and a regular PVT setting with no gamification elements, where they were to rate their intrinsic motivation after each session, accordingly with a questionnaire constructed from the Intrinsic Motivation Inventory format.

The hypothesis testing reported that, although the ratings were relatively high, there were no statistical significance between the gamified version and a regular PVT setting, for the patients. On the other hand, the results from the students indicate relatively low rating scores with a statistical significance in interest and enjoyment between the implemented application and a regular PVT setting. With follow-up interviews, it was possible to address many of the issues the application contains with suggested solution in mind.

The issues mainly consist of game feedback or game content, such as the lack of a proper game introduction for a better onboarding experience for new users. Other issues such as missing or 'polished looking' feedback for various user interactions were also noticed by the participants. Although many of the issues are subtle in nature, they add up to the overall impression of the application, particularly first impressions, which is important for maintaining users' interest and motivation for keep playing the application. And since the literature reports that gamification is an increasing phenomenon and has proved that it can be a successful business method, thus it might be worthwhile for perceiving the project as merely a stepping stone for investigating the PVT session in gamification settings, and that future iterations should then aim to address the issues extracted from the interviews by implementing appropriate solutions, and yield a higher intrinsic motivation for the application on users as a result.

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Appendix A

Appendix: Interview with Jan Ovesen

The following appendix shows the interview with Jan Ovesen, MD.

Interview. Jan Ovesen, MD.

Validation of PVT setting

Q. Starting with an introduction, could you please describe what you do and what your experiences are within the profession regarding sleepiness and PVT settings?
A. I work with patients that suffer from different sleep disorders, particularly patients with sleep apnea and sleep insomnia. The patients with sleep apnea often report that they tired, having difficulty with falling asleep, lacking energy, difficulty with concentration along with decision making for high intellectual task oriented work. Patients with sleep insomnia report the same symptoms as patients with sleep apnea, that they are tired, having difficulty with falling asleep with consistent sleep hours, which leads to fragmented sleep and less sleep time in bed compared to a person without sleep insomnia.
A. The work started for 31 years ago, with primarily children that suffered sleep apnea. At that time, in the '70s, sleep apnea was still relatively new and as one of the few in Denmark, I was among the pioneers in the field of research. And since early '00, the shift of focus has been extended to various sleep disorders, including sleep apnea and insomnia.

Q. Basner and Dinges have proposed a standardized framework for PVT setting with specific design criterias. And in consideration of the application's foundation which follows the proposed framework for PVT setting from Basner and Dinges - what is your experience with the following 10 design criterias; (is it usual to use such criterias and how relevant are they?)

- **Test duration; 10 minutes?**

A. I think the 10 minutes duration is very important, because the duration is long enough to overcome the acute 'energy kick' for subjects that are more than 24 hours sleep deprived. The extra reserve of energy is something we all have for use in dire or emergency situations, however, the extra reserve of energy will rapidly depletes, particularly if the situation is a repetitive task. This has been shown in previous research, that the first 2-3 minutes, the person respond normally, and after the 3-4 minutes, the reaction time steadily decreases.

- **Stimulus; Visual millisecond counter in rectangular box?**
  Feedback; Displayed for 1 second?
  Button fail-to-release; Displayed if not released after 3 seconds?
  Wrong key press; Displayed if the wrong response button is pressed?

A. That is a standardized format which has been chosen, however I am sure other solutions exist as well.

- **Inter-stimulus interval; 2-10 seconds?**

A. 2-10 seconds sounds reasonable, because the stimulus itself has a little arousal effect on the brain and it takes some time for the brain to balance out the arousal. Which is why 2-10 seconds are used here, however, it is also possible to make the ISI longer, as seen in some previous studies. As a result, some of the sleep deprived test persons simply fell asleep!

- **Errors of commission; Response without a stimulus or RT < 100ms?**

A. If a test person simply keep clicking the button without any stimulus active, he might at one instance hit the button with RT less than 100 ms, and this is of course due to the continuous clicking and less about reaction time.

- **Errors of omission; RT > 500ms?**
  Time out; Timer > 30 seconds?

A. If the RT is over 30 seconds, that would indicate a high risk of falling asleep. And the error of omission would indicate a decreased response time and possible sleep deprived, compared to persons without sleep disorder.

Q. Considering that the application has omitted the two last design criterias, namely, the button fail-to-release and wrong key press, for the purpose of simplicity and thus do not account for such events. Do you think it has any significant effect compared to the full setup? And if so, why?
A. No, I do not think it has any important implications as long as the application gives a decent instruction for how to properly do the tasks.

Q. In addition to the proposed design criterias, Basner and Dinges also proposed 10 outcome metrics. What is your experience with such outcome metrics and how would you describe the contribution of each metric?

- **Mean RT, mean 1/RT (reciprocally transformed RT or response speed), median RT, number of false starts, number of lapses, lapse probability, number of lapses and false starts, 10% fastest RT, 10% slowest 1/RT, performance score.**

A. The outcome metrics are important and some might be more relevant than other, depending on the setting. My experience with such outcome metrics has primarily been on the number of lapses and the reciprocally transformed RT. The response speed is great for providing an overview of their sleepiness state regarding reaction time for repetitive task oriented work. The number of lapses is great for indications of risk for falling asleep. Patients have even told me during tests that they were surprised about even missing several seconds of a stimulus or altogether, resulting in a time out. This is often because the overestimation of their own sleepiness state, they would rate themselves as not sleepy while the numbers show otherwise. Which is also why it is important to measure the sleepiness state objectively, otherwise the patients would hardly believe it for themselves, particularly those who suffer sleep deprivation.

Application usage

Q. Since PVT sessions are usually conducted in laboratory settings, thus creating an artificial incentive for users to perform a PVT session. Do you think users would be willing to perform PVT outside of the laboratory setting? And if so, is there any specific target group that PVT is more relevant for?
A. The conventional equipment for PVT would be easier to set up in laboratory settings due to the amount of space required. However, with PVT applications on a PC, laptop or even a smartphone, the accessibility would without doubt be much easier for everyone. With that said, I do also think people would be willing to do the PVT sessions because it would not require many minutes to set up a test session, and the data would easily be logged in the background on run-time. So for sleep deprived patients, a likely scenario would thus be they get the application by simply downloading the application onto their smartphone or tablet, and then told to use it before treatment and after treatment at home, and the data would then be automatically logged for further evaluation.

Q. Considering that a single PVT session is usually 10 minutes. How often would the user have to do the session in order to create a reliable representation of his sleepiness state?

- **Per day, per week, per month.**
  How significant is a single session?

A. At the beginning before treatment for patients, I would just let them try the PVT once and as treatment starts, then preferably the patients would schedule a systematically routine for taking PVT sessions. With traditional equipment it was difficult to set up large schedules for patients because the instruments required a laboratory setting, but with PVT application on a smartphone or tablet, it would be much easier to schedule such routines. This also means by systematically monitoring the sleepiness state through PVT over several months would allow a more precise overview of their sleepiness state.
A. So, a likely scenario would be to tell a patient to do a PVT session before treatment, then log the data and save it for later evaluation. After a few weeks of treatment and we see improvements, then I would ask the patient to do another PVT session, and compare the data for any improvements. With an application on smartphone or tablet, it would also be applicable to simply tell the patient to do PVT sessions several times per day at home, and log the data for comparison. In addition, research about the day variation regarding sleepiness would also benefit of such medium, since current research are still very limited in that field.

Q. At what time or condition should the user perform the session?
A. As a rule of thumb, in the afternoon people should have a normal reaction time, because that should translate roughly to 8-10 hours of wakefulness. It is at the 14-16 hours of wakefulness where decrease in performance is visible.

Q. At what time or condition should the user not perform the session?
A. That would then be at night or close to midnight, because it is natural to be tired at that time with 16-18 hours of wakefulness. At that time, you would get pathological data which is natural due to the mental state of tiredness and sleepiness.

Q. Due to the lengthy duration of the PVT, the time-on-task and other factors might contribute to the factor that the user becomes too unmotivated to continue the session and thus disturbing the data logging and outcome metrics. Have you experienced such behavior before in which users prematurely stops the PVT session?
A. I have experienced patients that simply fell asleep during a session! That has mainly been in combinations with driving simulators, where the driver could simply not keep the eyes open and the car on the road and ended in the ditch. Looking in perspective, the driving simulators were relatively simple in nature and similar to the PVT, as the task was to keep the car on the road.

Q. In the case of the application, a user might prematurely quit the session for various reasons, such as boredom or other tasks that need to be done. If so, how would you suggest to handle the logged data of the current PVT session?
A. In the case of premature ending of a session, I would suggest to simply discard the data logged for that session.

Q. The current implementation also provides the user with a pause button, for pausing the current PVT session, and an unpause button to continue the session. Would such feature be acceptable compared to a regular PVT session? If any, which implications would the feature contain?

A. In principle people would be able to ‘cheat’, if they were using the application at home, because they could simply click on the pause button and take a small break to regain some energy and thereby gain a small boost in performance. That is of course not ideal, and perhaps the pause screen could bring up some text, informing the user that it is not beneficial for reliable data representation.

Q. Currently, the implementation also only logs the data for a single session at a time. However, do you think it would be beneficial for the user to be able to see the data over a period of time? And how would you suggest the data to be represented?
A. Yes, absolutely. I think it would be very beneficial to log the data over a period of time. So instead of a single data logging before the treatment, you could ask the patient to do a couple of sessions and thereby have a few data points for reference. But also during treatment, it could just as well act as a motivation by letting them see their improvements visually and objectively, instead of relying solely on their own subjective rating.

Q. In addition, would you suggest the information be available to sleep doctors as well? If so, would the current metrics be enough or should there be any additional data logging?
A. Yes, absolutely. And I think the current metrics are already a robust toolbox, but I am also sure other metrics will appear in the future, as more knowledge and research is done.

Degree of freedom for gamification

Q. Considering the design criterias suggested by Basner and Dinges, do you think the following criterias are adjustable / tweakable for creating a varied gameplay experience?

- **Duration, ISI (does it have to be 2-10 seconds), false start (does it have to be RT<100ms), lapse (does it have to be RT>500ms), time out (does it have to be 30 seconds).**

A. Since many of the factors are still relatively uncovered regarding different settings, particularly duration, I could imagine that it would be adjustable and that it is something that needs to be tested on. The ISI needs to be randomized in an interval range but different ranges could also be tested on. For the false start and lapse, that is more a neurophysiological matter, as how fast a normal reaction time is supposed to be.

Q. The current implementation are supposed to have three interval thresholds of reaction time, for rewarding the user depending on the reaction time performance. Do you have any suggestions of how such thresholds could be outlined?
I think the current intervals suit well, in that the size of the fish depends on the performance. Usually in such games, points would be earned and if enough points are accumulated, some kind of badge is awarded. The thresholds could be tested on people with normal sleep variation and then perhaps set the outline. Such as different outlines for, young and elderly people with good sleep, and patients with good sleep. Since we have to start somewhere, and the current experience with such format is very limited.

Q. Would the thresholds be adjustable between game levels in regards to the standard 500ms lapse?
It might be possible to adjust the thresholds accordingly to the sleepiness state of each user. So that if a person that is heavily sleep deprived would play a stage that has different thresholds for the fish than a person without sleep deprivation, to give a chance to the heavily sleep deprived person to catch the bigger fish as well, and thereby keeping the incentive to do the sessions.

Appendix B

Appendix: Test Evaluation

The following appendix shows the consent form and the questionnaire for the test sessions.

Gamification of PVT Setting Consent Form

Researcher: Long Thanh Truong
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What you will be asked to do: You will be presented with a game which contains tasks involving reaction time and sustained-attention.

1. In order to start a game level, you must click at the appropriate locations on the screen.
2. Once a game level is started, the task is then to click on a green circle that appears on the screen, as fast as possible.

Before and during the game level, you are welcome to explore the other features of the game.

3. Once the game level is completed, the test conductor will hand you a questionnaire to fill out. The questionnaire will contain questions regarding your experience towards the use of the game.

The questionnaire will approximately take 4-5 minutes.

Risks or discomforts: No risks or discomforts are anticipated from taking part in this study. If you feel uncomfortable with a question or during game play, you can skip that question or withdraw from the study altogether. If you decide to quit at any time before you have finished the game or the questionnaire, your answers will not be recorded.

Taking part is voluntary: Taking part in this study is completely voluntary. If you choose to be in the study you can withdraw at any time without consequences of any kind.

Your answers will be confidential: The information provided by you in the questionnaire will be used for research purposes only and completely anonymous.

Session and game video recording:
It is OK to record my interactions with the game on video for research purposes, e.g. analysis of what happened. YES NO

It is OK to use the video material in a scientific publication or presentation.
YES NO

Statement of Consent:
I have read the above information, and have received answers to any questions. I affirm that I am 18 years of age or older. I consent to take part in the research study of Gamification of PVT Setting.

Signature: ______________________________ Date: ____________

Questionnaire

1. What is your gender?

Male _____ Female _____

2. What is your age?

Years old _____

3. Do you have any prior experience with applications / instruments that measure your reaction-time based on visual cues / stimuli, similar to the game you have just tried?

Yes _____ No _____

If no, continue on from question 5.

4. The following questions concern your prior experience with applications / instruments that measure your reaction-time based on visual cues / stimuli. For each question, please indicate how true the statement is for you, using the following scale as a guide:

1	2	3	4	5	6	7
not at all true			some what true			very true

- I believe that doing the activity could be of some value for me.
- While I was doing the activity, I was thinking about how much I enjoyed it.
- I believe that doing the activity is useful for improved concentration.
- The activity was fun to do.
- I think the activity is important for my concentration.
- I enjoyed doing the activity very much.
- I think it is an important activity.
- I felt like I was enjoying the activity while I was doing it.
- I thought it was a very boring activity.
- It is possible that the activity could improve my sleep habits.
- I thought it was a very interesting activity.
- I am willing to do the activity again because I think it is somewhat useful.

- I would describe the activity as very enjoyable.
- I believe doing the activity could be somewhat beneficial for me.
- I would describe the activity as very fun.
- I would be willing to do this activity again because it has some value for me.

5. Do you have any prior experience with digital games?

Yes _____ No _____

If no, continue on from question 8.

6. Please write down which type of game genres do you prefer to play?
(RPG, action, adventure, puzzles, casual, hardcore, etc.)

____

____

____

7. Please indicate how many hours per day do you approximately spend on digital games?

Hours per day _____

8. Please indicate in minutes for how long time you think you spent on playing the game that you have just tried.

Minutes _____

9. The following questions concern your experience with the game you just tried. For each question, please indicate how true the statement is for you, using the following scale as a guide:

1	2	3	4	5	6	7
not at all true			some what true			very true

- I believe that doing this activity could be of some value for me.
- I believe I had some choice about doing this activity.
- While I was doing this activity, I was thinking about how much I enjoyed it.
- I believe that doing this activity is useful for improved concentration.
- This activity was fun to do.

- I think this activity is important for my concentration.
- I enjoyed doing this activity very much.
- I really did not have a choice about doing this activity.
- I did this activity because I wanted to.
- I think this is an important activity.
- I felt like I was enjoying the activity while I was doing it.
- I thought this was a very boring activity.
- It is possible that this activity could improve my sleep habits.
- I felt like I had no choice but to do this activity.
- I thought this was a very interesting activity.
- I am willing to do this activity again because I think it is somewhat useful.
- I would describe this activity as very enjoyable.
- I felt like I had to do this activity.
- I believe doing this activity could be somewhat beneficial for me.
- I did this activity because I had to.
- I believe doing this activity could help me do better with sleeping.
- While doing this activity I felt like I had a choice.
- I would describe this activity as very fun.
- I felt like it was not my own choice to do this activity.
- I would be willing to do this activity again because it has some value for me.