MAKING BETTER SERIOUS GAMES
FOR CHILDREN WITH ADHD
Guidelines for Designing Motivational Video Game Training

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Abstract

This study examines how serious games may be designed and developed to contain engaging working memory (WM) training exercises. Video games have a high potential as WM exercise environment for children with ADHD, but it is still difficult to create a long-term training solution due to their problem to retain attention. This thesis aims for better understanding of ADHD children's motivation to be trained by describing the creation of a game prototype that was designed with the help from WM experts, workshops with designers working on previous prototypes of the same game, guidance from medical doctors specialized on ADHD, and by using a methodical formal game design approach along with frequent user tests. The results of the presented prototype showed an increase in play-time and in retention of player’s attention over time in comparison to the previous prototype. The study concludes how game design resonated with the target audience.

Keywords: ADHD, working memory, serious game, attention, engagement, motivation, game design, perception learning, case study
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1 Introduction

In recent years, serious games have started becoming more understood, more researched and more used in the field of healthcare (Giunti et al. 2015). In spite of their tremendous potential, they are not being prescribed and widely accepted by authorities as an official treatment yet—at least not in the specific area this study is going to pursue—attention deficit hyperactivity disorder (ADHD) in children. Not only games can evaluate and diagnose this disorder, but also they can help with the therapy, for instance, by improving the effective functions (impaired in these patients) in engaging, novel ways scalable to individuals’ needs (Diamond and Lee 2011). Although there has been some attempts to create such games, so far there is none that would be both medically effective and engaging enough to become a long-term solution (Luman et al., 2005; Shanahan et al., 2008). In the particular case of catering to patients with ADHD, it is especially important that engagement goes hand in hand with clinical effect criteria due to patients’ difficulties in maintaining their attention. The basic characteristics of this disorder along with its usual treatment and serious games already created will be described in the following chapter.

This disorder can have severe negative effects on patients’ day-to-day life and can become a potential hindrance during future endeavours. There are certain methods (described in Chapter 2) that have proven to have a positive impact on the main symptoms. While previous methods have shown to be clinically effective when successfully employed, the biggest challenge is actually in their form of administration. Outside of clinical studies or in more strict medical contexts, it is difficult to create ADHD beneficial exercises that are interesting or engaging enough to obtain long-term attention of the patients, which can often be required for exercises and treatments to be effective. That could easily become a vicious circle, since it is necessary to get attention from those who are generally lacking it and the ultimate goal is to treat this very state of inattentiveness.

There has been studies and computerized tasks that showed success in the treatment of working memory, which is one of the effective functions impaired the most in children with ADHD. But while games show a great deal of potential in this area—since they are popular among young people (Rideout et al., 2010; Giunti et al., 2015), can capture their attention more easily than other means (such as paper tests; Bandura, 1986; Giunti et al., 2015), and that they ‘naturally’ contain challenges that exercise a wide variety of cognitive abilities—it is still not a trivial task to integrate clinically proven training procedures and engaging gameplay into a cohesive entity. The process of uniting elements of clinical treatment and gameplay mechanics into beneficial exercise poses a difficult game design challenge. Regardless of the positive outcome such existing games have shown, no game has been developed in a form sufficient to replace medications, as these games usually require a clinical settings with the therapist thorough supervision due to the lack of engagement in the playing alone (Luman et al., 2005; Shanahan et al., 2008). Hence the main problem is how to create a game that would effectively contain exercises beneficial for children with attention difficulties, but that also does not cause frustration or boredom which eventually leads to their abandonment of the game (and, by extension, the training). Despite the positive medical impact some of the existing WM games have had (Klingberg et al., 2005; Deveau et al., 2014; Mackey et al., 2011), the training is still not enjoyable enough to become a long-term solution. These games
require external incentives such as encouragement of parents or even therapist continuous supervision (Luman et al., 2005; Shanahan et al., 2008) and hence do not pose an ideal solution. This issue could be the result of incorrect attitude towards the way how those games are being designed, namely an excessive focus on their medical efficacy while ignoring the engaging aspect or not acknowledging fully its importance.

In this thesis, methods for designing and developing games for the purposes of WM training will be examined. It requires following of certain general design concepts and principles as well as thorough testing and guidance of a medical doctor. To exemplify how these two aspects of serious games creation can be merged to create WM training games, specifically with ADHD children as the target audience, the design and development of Memory Island, a game prototype intended for such a purpose, is used as a case study. The prototype was developed at Lundelab, a small company that staffs both game development practitioners and medical doctors. The prototype’s main goal is to achieve a higher rate of retention during visual-spatial WM exercises among the target audience. Given the positive impact that WM training can have for children with ADHD, it is important that they stick with the training programmes recommended to them by their medical professional. However, given the nature of ADHD and the difficulties it can cause when it comes to the retention of attention, children can often stop progressing through their training programmes due to lack of motivation and engagement. This prototype was, in essence, created to solve this problem by capturing the attention of the children diagnosed with ADHD for as long as possible and work as the first phase and the showcase of an upcoming serious game aiming for a long-term engaging ADHD treatment. At the end of the development process, the prototype was tested, evaluated and compared to a previous work done by the company. In that way, not only can this study show examples of how the development of a WM training game can be conducted, but it also includes an examination of what the target audience felt about the game’s mechanics and aesthetics, and how well various aspects of the game worked when it came to increasing motivation and retention.

In the last chapters, the implementation of the prototype as well as its tested results will be discussed and recommendations for future developers will be outlined.
2 Background

In this chapter, some fundamental theories and concepts related to ADHD, and treatment methods associated with the disorder, will be described: what does the diagnosis entail; its characteristic symptoms and consequences; common ways of treatment, including serious games and other forms of computerized training; and it will be also outlined what has already been done in this area.

2.1 ADHD & Its Symptoms

Traces of ADHD can be found in the literature since the nineteenth century (Lange et al. 2010), however, its contemporary concept as defined in the American Psychiatric Association’s Diagnostic and Statistical Manual DSM-IV-TR (American Psychiatric Association, 2000) is relatively new. Its characteristic symptoms such as inattention, excessive motor activity, impulsivity, and hyperactivity described by various authors during the last 200 years are consistent with the modern diagnostic criteria for ADHD.

2.1.1 Working Memory and Other Executive Functions

It is thought that self-regulation deficits are the core of the ADHD syndrome which results in deficient executive functioning. Executive functions such as temporal processing, working memory (WM) or response inhibition are crucial for effective self-control, since they allow individuals to regulate their emotions, thoughts and behaviour. This results in significant limitations in everyday life such as inability to pay attention, keeping track of homework and so forth. Children with ADHD exhibit severe impairments in response (behavioral) inhibition and WM (Dovis et al., 2012; Prins et al., 2011).

WM is essential for retaining and processing temporary information and making response based on the internal representation after a delay. This is crucial for complex cognitive tasks such as learning or reasoning and therefore WM impairment has severe impact on many casual activities performed by humans on daily basis (Nikoukaran and Moradi 2014). Impaired WM is not present solely in ADHD condition, it is observed as well in schizophrenia, stroke, mental retardation or traumatic brain injury (Klingberg, 2010).

So called visual-spatial WM is considered the most impaired neuropsychological function in children with ADHD. It is responsible for holding and manipulating visual-spatial information. This results in difficulties with remembering what individual was doing and what he or she has to do in order to accomplish the current task (Dovis et al. 2012).

2.1.2 Role of Motivation

Alternative theories assume that children with ADHD are abnormally sensitive to reinforcement and insufficient motivation can therefore be the main problem standing in their way to effective functioning. These children need stronger stimulation in form of reward, punishment/response cost, feedback or combination of those; an immediate reward has proven to be especially effective (Dovis et al., 2012; Prins et al., 2011). They also tend to be poor self-observers and often low in self-confidence regardless of their actual success, so some of them frequently require external reassurances (Hallowell et al. 2011).
Their need for stronger stimulation can be also explained by hypothesis that they suffer due to non-optimal energetic state necessary for efficient information processing (Sergeant et al. 1999). Effort, related to motivation, is considered the energy needed to accomplish the task. Thus with sufficient reinforcement performance can be improved.

2.2 Prevalence

ADHD is currently considered to be the most commonly occurring neurobehavioral disorder in children (ATTENTION-DEFICIT, 2011; Visser et al., 2007; CDC, 2005), but it can often follow an individual into adulthood (Arolt, 2008). Results of meta-regression analyses have shown that the worldwide prevalence has been estimated at between 5.29% (Polanczyk et al. 2007) and 7.1% in children and adolescents (Willcutt, 2012). According to the results of National Survey of Children’s Health conducted and analysed by Centers for Disease Control and Prevention (CDC), 11% of US school-aged children (4-17 years) had received an ADHD diagnosis by a health care provider by 2011 (Visser et al. 2014).

The percentage of children diagnosed with this disorder continues to increase rapidly, from 7.8% in 2003 to 9.5% in 2007 and to 11.0% in 2011. The average annual increase was 3% from 1997 to 2006 (Akinbami et al. 2011) and approximately 5% from 2003 to 2011 (Visser et al. 2014). This trend is getting far beyond what the mental health system of most countries can manage (ATTENTION-DEFICIT, 2011).

The average age of a child diagnosed with ADHD is 7 years old, but the symptoms usually manifest themselves between the age of 3 and 6. According to parent reports, the average age of diagnosis decreased with its severity (Visser et al. 2014):

- **8 years**—the average age of diagnosis for children having **mild** symptoms
- **7 years**—the average age of diagnosis for children having **moderate** symptoms
- **5 years**—the average age of diagnosis for children having **severe** symptoms

There are also some significant correlations of gender and ADHD probability: boys (13.2%) are almost three times more likely to be diagnosed than girls (5.6%). Prevalence was more than four times higher for children using English as the primary language compared to other languages. Differences in socio-economic background also had an impact on diagnosis probability, as the children from poor households (households below 200% of the federal poverty level) were more likely to be diagnosed (Visser et al. 2014).

2.3 WM Treatment

Improvement of working memory can be attained by training of the corresponding cognitive system (Klingberg, 2010). Hence it is truly beneficial to detect this impairment in early childhood ideally before school age. Children can be trained to overcome many of the aforementioned issues associated with ADHD by assessing and exercising their working memory. This can be done in various ways ranging from paper-and-pencil tests and questionnaires, to computer games (Nikoukaran et. al 2014).
According to previous studies (Thorell et al. 2009), children who had undergone WM training showed a significant improvement on trained tasks, but they also improved on non-trained tests of verbal and spatial WM. Their overall abilities to remain attentive in everyday situations was affected in a positive way as well. Due to the strong connection between ADHD and WM, WM training could be an important component in diminishing ADHD symptoms.

In terms of improving motivation and task performance, the impact of form and the intensity of reinforcement has been discussed and tested in several studies (Prins et al. 2011). Children with ADHD appear to have especially profound response to reinforcement in form of a reward of social nature. Dovis et al. (2012) also tested and compared impact of monetary and computer game rewards. Computer gaming could be especially effective due to attractive, consistent and dynamic stimulation.

2.3.1 Training Methods
The level of individual’s WM condition is usually measured by his or her Working Memory Capacity (WMC). It can be assessed by various tasks ranging from recalling short list of items (numbers, words, spatial locations etc.) to complex span tasks that require manipulation with memorized data. The following neuropsychological tests has been commonly used for this purpose:

- **Block design task**: the subject is to arrange blocks that are either white or red or both white and red in a way the blocks form a specific pattern (Wechsler, 1995). This task measures spatial perception as well as problem solving.

- **Stroop task**: the subject is provide with randomly present color words ‘green’, ‘blue’, ‘red’ and ‘yellow’. Sometimes the color in which words are printed corresponds to the meaning of the words (e.g. the word "green" is written with green coloured letters; Lezak et al. 1995). At other times they are incongruent (the word "green" is written in red coloured letters) and the subject is to name the actual color of the printed word. A subject’s ability to inhibit the prepotent response of reading the words is being tested here.

- **Span board task**: Ten blocks are situated on various positions on a brick. A sequence of blocks is pointed by the tester and the subject is to reproduce the sequence (Wechsler, 1981). This test measures visual-spatial WM.

- **Raven’s matrices**: The subject is provided with a matrix of figures with one blank position. The participant is to deduce the right figure that is missing based on the relationship between rows and columns (Raven, 1995) Inductive reasoning ability is being targeted here. More recently developed and frequently used Bochumer Matrizen test (BOMAT) is similar to Raven’s matrices (Klingberg 2010).

- **Continuous performance task (CPT)**: The participant is visually or auditorily presented with a continuous stream of letters or digits (Korkman et al. 1998). He or she has to react when a specific combination of stimuli (e.g. 4 followed by 2) occurs. The aim of this task is to measure sustained attention and vigilance.
• **N-back task**: A sequence of stimuli is presented to the subject, he or she has to respond when the current stimulus matches the one shown already \( n \) steps earlier (Kirchner, 1958). Naturally, the difficulty of the task can be easily scaled by increasing \( n \) variable. For instance, illustrating the 3-back test, the tester could read the following sequence of letters (while making a little delay between each letter):


The participant is supposed to respond when the bold letters are read, since they are congruent to the letters presented three steps earlier.

This task is one of the best known for WM assessment and training (Gazzaniga et al., 2009; Deveau et al., 2014). It focuses on “memory updating”, as the subjects need to update the state of the sequence in their mind continuously. N-back training results in wide-ranging improvements including executive functioning (Salminen et al. 2012), episodic memory (Rudebeck et al. 2012), and even fluid reasoning (Stephenson and Halpern, 2013) and WM functions that were not trained (Lilienthal et al. 2013). The improvements in the untrained fluid intelligence tasks are the result of sufficient amount of training (Stepankova et al. 2014) combined with achievement on the training task (Jaeggi et al. 2011).

Due to its plastic nature, an analogy between a muscle and WM could be drawn easily, as it can be strengthened by gradually more and more challenging exercise (Shipstead et al. 2010). Hence the adaptive WM tasks that are always on the edge of the subject’s ability and therefore pose a certain challenge are needed.

### 2.3.2 Computerized WM Assessment

As mentioned earlier, one of the main symptoms of ADHD is impaired WM and it is of utmost importance to be able to assess it effectively. Games can provide suitable environment for making assessment systems due to their popularity among young people, fun and voluntariness aspects and unique features. Nikoukaran et. al (2014) introduced such a game (working memory test) and evaluated its validity by comparison made on a group of pre-school children. A strong connection between game and test measures positively confirmed the game as an assessment tool (Nikoukaran et. al 2014).

The Monkey Game (Van de Weijer-Bergsma et al. 2015) is an example of game that can assess WM–this time the verbal one–and was intended for children with ADHD. It is usual to use complex span tasks (such as reading span or counting recall) or backward span tasks (such as word span backward) to assess verbal WM in children. The point of backward span tasks is to enhance WM load; they usually start with a short list of verbal items that child has to remember and the number of items increases with each successful trial. After those items are presented, the child has to recall them in a backward way. The monkey game uses this concept and its theme was deliberately chosen due to monkey’s tendency to imitate. After finishing each level, various cartoon monkey animations are shown in order to sustain children’s engagement. Children have to remember several spoken words and recall them backward by clicking on the words presented as images. It was clinically tested and it was confirmed that it can be used for self-reliant verbal WM assessment in children within a classroom settings. It appeared to be an effective and low-cost solution.
2.3.3 Computerized Training

Computerized training is one of the scientifically proven approaches improving executive functions in the early school children (Diamond and Lee 2011). *CogMed* (2001, figure 1) is the most successful and most researched computerized WM training program (Holmes et al., 2009; Klingberg et al., 2005), which uses computer games with gradually increasing level of working memory difficulty. In a study conducted with *CogMed* (Klingberg et al. 2005), children with ADHD or weak WM spans showed improvement in the games they practised as well as in other WM tasks.

![Figure 1](image)

CogMed (2001)’s RoboMemo games

But what makes such games or memory games in general effective? There has been a study (Deveau et al. 2014) aiming to answer that question. They produced a working prototype based on modern game design and perceptual learning principles aiming for motivation, reinforcement and promoting learning. It was suggested that to make the game successful, it is necessary to integrate knowledge of memory systems with that of brain plasticity and modern game design principles possibly inspired by successful off-the-shelf games.

Mackey et. al (2011) tried to randomly assign children (age of 7 to 9) to speed training or reasoning with computer and non-computer games. The results of this hybridized study showed that those who had undergone speed training did not improve on reasoning and the other way around.

2.3.4 Other Approaches

Apart from the gaming approaches, there are many others which usually requires certain mindfulness, concentration or awareness training. Namely, they can be martial arts, yoga and sports in general with mindful execution or also special classroom curricula (Diamond and Lee 2011).

2.4 Serious Games

It is known that games have a history far beyond the more contemporary concepts that are associated with games and gaming. In fact, they are older than stories and their importance is tremendous not only for humans but among animals as well. For instance, young bear cubs are playing by fighting with each other, but it is this very game experience that makes them ready for a real combat encounter in the future. Serious games can be understand as any meaningful games not meant for pure entertainment (Deterding et. al 2011). Such games
have a very long history especially in military tactics, apart from the obvious chess, ancient sand tables used by the Roman empire (Smith, 2009) can be named.

Serious games unlike other forms of treatment could be not only more accessible for children but also more effective. Introducing such games can, however, be difficult in the group of intended recipients for many different reasons. The aim of this study is not to focus on dealing with this introduction and problems connected to it, rather their potential and specific ways how they could be beneficial will be discussed.

Dovis et al. (2011) study concluded that strong incentives helped normalize persistence of performance in ADHD children. The computer gaming efficiency appeared to be comparable to high intensity monetary reinforcement (10 euros). This finding confirmed that game strategies could be a cost-effective solution for performance training. Serious games indeed can be very useful, as comparing gaming format to a regular computerized WM training showed positive results in terms of enhanced motivation and training performance (Prins et al. 2011).

2.4.1 Recommended Practices For WM Games

The human brain can work efficiently in natural environments in which behaviour is guided by multiple sensory information and interactions (Ghazanfar and Schroeder, 2006; Driver and Noesselt, 2008). According to several studies, the training with visual-auditory stimuli is more successful in terms of improvement and learning speed than visual training only (Seitz et al., 2006; Kim et al., 2008; Deveau et al., 2014). Deveau et al. (2014) study that reviewed recent WM training approaches suggests using multi-modal object presentation in WM games in a way that each sense complements the other. For instance, for a player with limited visual perception capability, concordant audio stimuli will be beneficial.

Demonstrated in perception learning (Xiao et al., 2008; Deveau et al., 2014), there is another way how to increase effectiveness of this specific training, namely to train with multiple stimuli. For instance, so called “double training” can exhibit broad transfer when more stimuli are trained. However, the diversity of stimuli could also lead to the unwanted transfer to untrained tasks (Schmidt and Bjork, 1992). According to perception learning, the appropriate arrangement of multiple task elements can determine what will be transferred. Inappropriate arrangement, such as different stimuli order based purely on random selection, can hence result in poor learning results (Seitz et al., 2005; Zhang et al., 2008). It can as well lead to greater distraction and Deveau et al. (2014) study recommends integrating higher degree of congruence between motivational aspects and the actual training stimuli.

In order to achieve learning success, perception learning can be projected into game design concepts. For example, a constant feedback can lead to profound reinforcement to trained stimuli (Seitz and Watanabe, 2009; Adams, 2013). Adams claims “most critically, they need information about whether their efforts are succeeding or failing, taking them closer to victory or closer to defeat”. Apart from motivation (Shibata et al. 2009) and ensuring self-confidence of the players regarding their performance (Ahissar and Hochstein, 1997), another good game-design principles such as setting clear goals (Salen and Zimmerman, 2004) or taking care of right difficulty balance (adaptive training) need to be taken into account (Deveau et al. 2014).
3 Method

This chapter presents the research problem of this study and it explains how the research question was examined and evaluated.

3.1 Research Problem

Despite the positive medical impact some of the aforementioned games have had (Klingberg et al., 2005; Deveau et al., 2014; Mackey et al., 2011), all of them still struggle with making the training enjoyable enough to become a part of children’s regular daily activities. This issue can essentially render these treatments ineffectual if sufficient in-game motivation or external incentives (including supervision) are not provided (Luman et al., 2005; Shanahan et al., 2008). For example, while CogMed has shown to be effective in some environments of use, it has not proven to be effective when used without direct researcher supervision (Klingberg, 2010; Klingberg et al., 2005). Similar shortcomings were also found with other training programmes (Owen et al. 2010).

When the treatment programmes fail to engender enough engagement to make them a regular activity, they instead relies on parents or even therapists to continuously supervise and encourage children to play, and are hence not particularly good. This is the basis for the problem with many ADHD treatments: the form of administration is an obstacle for clinically proven beneficial exercises to become a part of their target recipients’ everyday life. If the purpose of using games as WM training treatments is their ability to foster engagement and motivation that makes children want to engage with them regularly, this fundamental issue needs to be resolved. This problem could be the result of flaws in the design processes of previous WM training games and computerized training software, namely an excessive focus on their efficacy and strict adherence to clinical procedure while ignoring the engaging aspect or not fully acknowledging its importance.

3.2 Research Question

This thesis aims to tackle the issues associated with serious games for ADHD children's WM training by designing and developing a prototype that attempts to balance engaging game mechanics and clinically proven WM exercises.

The aim of this research project is not to create a perfect training serious game, but rather explore the ADHD children as players and provide some possibly valuable findings and guidelines for other designers and developers interested in making games for such demanding audience. In the following chapters, the entire development including proposed design along with its implementation will be described.

Undoubtedly, the aforementioned memory training methods that work in terms of treatment will be integrated in the serious game prototype, but the main two questions that this thesis aims to answer are as it follows:
1. **How to make a serious game that will capture more attention of children with ADHD?**

By following methodical game design approaches together with recommendations from WM experts and guidance from designers with previous experience working on these types of games, the project should result in a prototype that is both sound from a medical perspective and a design perspective. In order to examine whether the design and development approach resulted in a good product, various methods of tracking player behaviours and gathering players’ opinions of the prototype will be used (which will be described further at the end of this chapter and in Chapter 5). Thus, by developing the prototype and testing it with members of the target audience, some general guidelines and recommendations for how these types of games can be designed.

2. **Are there any game challenges and mechanics that are especially efficient or inefficient when it comes to motivating children with ADHD?**

As described earlier, previous WM training games and computerized training solutions have had trouble with retention. By tracking and examining player's in-game behaviours and gathered opinions regarding their game experiences, this thesis also aims to examine exactly what type of game mechanics and components seem to be especially efficient (or not efficient) when it comes to engaging and motivating children with ADHD to participate in WM training exercises. For example, the prototype and the used evaluation methods may be used to identify whether players within the target audience might prefer intrinsic or extrinsic means of motivation, or whether their retention is dependent on immediate rewards as opposed to long-term rewards that are harder to obtain. Also, the impact of familiar game aesthetics on the player’s game experience will be evaluated and discussed.

### 3.3 Ethical Considerations

Despite all the potential serious games treatment has, the target group—children with ADHD—could be rather problematic concerning researching and analysis. Hence certain ethical considerations have to be kept in mind when executing testing.

The main difference between children and adults has to do with ability and power. The children vary and their development differ from each other greatly; adults have to adapt the language used for communication with them to make it as understandable as possible, they have to do checks and provide repetitions. In terms of power, children can feel oppressed and therefore incapable of expressing their own opinion due to adult authority. This particularly applies to abused children or children with disabilities. It is argued that the children should be involved actively in the entire research process so they can be empowered (Hill, M. 2005).

Due to the feeling of incompetence and weakness, children can be very vulnerable to persuasion and harm. Therefore it is utmost important to avoid any pressure within research and everything has to be well explained. There should be the interpersonal style involved and the research should reduce children’s desire to please, so the value and validity of what they
say is intact and unlimited. The authority image of researchers should be minimized by means such as using informal language or sitting in a position comfortable for the child (Hill, 2005).

Another issue is consent and choice. According to Helsinki declaration about biomedical research (World Medical Association, 2001) and Hill (2005), it is good practice to obtain the consent of children given that they can understand it. Naturally, it is difficult to determine when the child is able to do so and it varies greatly from child to child. The consent itself must be well informed and comprehensive for the children. Also, agreement from parents or relatives is usually a necessity. Without parents’, school’s or local authority department’s authorization it may be problematic to make contact with children (Hill, 2005).

Nowadays it is standard practice in medical research that all research proposals must undergo strict scrutiny by an ethics committee. Qualitative research should be guided at least by these following considerations: 1) protection (avoid children’s stress and distress), 2) welfare (contribution to children’s well-being), 3) provision (children should feel good about their contribution to research) 4) choice and participation (children should be allowed to decide about: a) termination of research, b) taking or not taking part, c) confidentiality boundaries). In general, there are many ethical considerations, codes and guidelines researchers have to go through before initiating or preparing research (Hill, 2005).

Even though the game prototype developed along with this study was tested on children under thorough supervision of a medical doctor specialized on children and youth, all the ethical considerations outlined had to be taken into account when preparing testing sessions and testing protocols. The parents were specifically included in the final test, they signed an informed consent (see Appendix D) and were well aware of the entire procedure including the study background and purpose.

### 3.4 Final Prototype Testing Session with ADHD Children

The last testing session was very different from the previous ones (Chapter 4), as it was done with children with ADHD and it was tested at home without the team’s continuous supervision. An introductory meeting with families interested in the computerized ADHD treatment was arranged and it was executed in a private hospital institution training centre Legevakt Vest in Oslo. The aim of the session was to familiarize the parents and children with such a treatment, working memory and plasticity of brain in general, but also to provide guidelines how to use the game prototype. The background was explained by two medical doctors, one of which had around 15 years of experience in this area, and the game was installed on the parents’ devices to give the children an opportunity to try it out, but also to ensure it would work properly. The informed consent (Appendix D) had been signed by all the present parents and they were instructed about certain basic rules for the testing (such as only one child can play at one device), informed about the anonymous way of collecting game logs and provided with support contact information in case of emergency.

On April 2, five families and six children of age from six to twelve attended the introductory session. They were given the game prototype and instructions to play it on daily basis for the following six days, while their playing tendencies were tracked. Each game session was to take at least ten minutes and was internally limited up to an hour per day.
Finally, the children took part in the last face to face meeting to answer the final questionnaire (Appendix D) that mostly dealt with their motivation to play the game and their general impression.

3.4.1 Raw data (telemetry)
At the end of each game session (closing the game), the following game session metrics had been stored as a serialized .JSON file locally and sent on the prototype developer's server:

- **Session start, Session End**
  - session time (from 0 to 3600 seconds)
  - difficulty level (the internal difficulty value)
  - visible level
  - gems

- **Task finished**
  - type (what task)
  - result (success, failure or out-of-time)
  - time spent
  - time given (how much time player had for this task)
  - difficulty level
  - visible level

- **Special events**
  - type (earthquake or falling into the water)
  - time spent

As a precaution, additional running logs had been stored locally. At the final meeting with the parents all the relevant local tracked data were collected and the local .JSON files were compared with those stored at the server. Hence in case of incomplete or missing session data, the additional logs could have been used.

3.4.2 Metrics, processed raw data
Accidental game start-up (sessions under 2 minutes with no in-game activity) data were removed along with time of inactivity (away from keyboard).

The following information has been extracted from the obtained metrics:

- overall and average time spent on playing the game over days for each player
- game progress over time (level, gems, difficulty)
• game success
• task selection tendencies

3.4.3 Success Ratio Data
In terms of measuring in-game success, two variables were used to reflect player’s subjective feeling caused out of free task selection but also objective and more complex one.

Apart from the simple success ratio that is calculated as it follows:

Formula 1: Success Ratio
\[
successRatio = \frac{\text{successfulAttempts}}{\text{allAttempts}}
\]
where \(0 \geq successRatio \leq 1\)

there was need to use another variable Cross-Task Success Ratio (CTSR) that would be more complex and reflecting player’s success cross all the tasks. It is calculated as it follows:

Formula 2: Cross-Task Success Ratio
\[
CTSR = \frac{\sum_{i=1}^{4} \text{successfulAttempts}_i}{\sum_{i=1}^{4} \text{allAttempts}_i + 1}
\]
where \(0 \geq CTSR < 1\)

3.4.4 Questionnaire
As the number of participants was very low to make any solid conclusions based on statistical analysis, the tracked behaviour data were used only to support information obtained from the questionnaires.

One part of the questionnaire deals with participants’ profile and their general impression concerning the game, while the other aims for understanding players’ motivation, playing tendencies and how they perceived game difficulty changes over time. It should also provide some feedback on individual tasks to find out what ways of training task presentation is generally acceptable and engaging.

All the results and their interpretation are discussed in Chapter 5.
4 Design and Development of the Game Prototype

The first part of this chapter describes the final prototype design and how it was motivated. The latter part explains the development in detail and allows the reader better understanding of the entire process. To see the results of the final prototype test, skip to Chapter 5.

4.1 Design Considerations

Even though the games can provide motivation needed for the training, in case of improper design, they can lead to task performance impairment or even weaken learning and test quality (Hawkins et al., 2013; Katz et al., 2014). Due to these risks and highly demanding and problematic audience’s nature, it is of utmost importance to come up with a meticulously planned and regularly tested game design. Hence the prototype development process is a combination of methodical formal approach with recommendations from WM experts, guidance from designers working on the previous prototypes, inspiration from successful relevant off-the-shelf titles and also with my own nine years of experience in game design and development.

The prototype was developed in a context where the involved team members had previous experiences with this type of game development. Thus, the early stages of the design process was informed by lessons learned from previous projects, which made it easier to circumvent or handle some basic pitfalls and challenges in this project. Before describing the novel approaches taken when designing and developing Memory Island, some of the knowledge gained from previous projects will be described first.

4.1.1 Previous Prototypes

There have been two main iterations of prototyping before Memory Island development:

The first version, Stones of Magic (Figure 2), was based on design by students at The Oslo School of Architecture and Design (AHO). The design documents were presented to a Norwegian developer called Agens, who made a working prototype. Stones of Magic was further developed by a game developer at Lundelab, and it is a functional yet never published game. The main idea of this prototype was to explore games as a medium for WM training.

Figure 2 Screen-shots from the Stone of Magic prototype, showing the main game-play (WM task concentrating on remembering certain patterns of stones)
The second version, *Mindcrafter* (Figure 3), was designed and implemented at Lundelab by a team that encompassed both a game developer and a medical professional from the field of neuroscience. The main idea of this version was to make a WM training game that was built upon the children’s existing gaming experiences and interests. The main concept of the game originated from an observation that all children treated by the medical professional at Lundelab had a common interest in playing the game *Minecraft* (2011). Thus the main strategy was to test how large the transfer effect for motivation was between the original *Minecraft* and Lundelab’s game using similar design and mechanics.

![Figure 3](image)

**Figure 3** Screen-shots from the *MindCrafter* prototype, showing a map of a navigation (left) and two WM task mini-games (right).

These two prototypes constitute two different types of development experiences which was helpful in guiding the design and development of Memory Island.

One of the primary lessons learned from *Stones of Magic* was the fact that it was very hard to find a balance between engaging game mechanics and WM training exercises. The team at Lundelab managed to find some traces of engagement, but their final judgement was that the prototype was not engaging enough to be considered a successful game-based training solution as it would not be able to reach sufficient retention with the target audience. The prototype was thus scrapped in favour of a pursuing new ideas with the *Mindcrafter* prototype.

During the development of *Mincerafter*, while it solved some of the issues identified during the *Stones of Magic* project, new types of challenges emerged. Probably the biggest issue with regards to the finished prototype for *Mincerafter* was that the children who tested it always wanted to play the least mentally challenging mini-game. Once the difficulty rose high enough that they were actually being challenged, they just exited that mini-game and started another one. Thus, the progression of increasingly challenging exercises designed by the developers never really got used by the players, which ran the risk of diminishing the effectiveness of the WM training.

On the other hand, the biggest positive result was how motivating "simple tricks" were for the children. Having recognizable graphics and frequent rewards was enough to make some of the children want to keep playing the game after 5 days worth of sessions that lasted up to 20 minutes even though the games themselves were extremely unpolished and not very funny. The children also reacted very well to the fact that their parents actually encouraged them to play iPad-games during the test period.
4.1.2 Key Experiences from Previous Projects
Based on the previous prototyping, Lundelab found out the following:

- The games NEED to be funny and rewarding to play to keep the children's attention.
- To attain such criteria, it is unnecessary to make a high depth of game-play complexity.
- Targeted children choose the path of least resistance when playing games.
- Discovering new aspects of the game was always positive for the children, even if they quickly concluded that this new aspect of the game was not interesting to them.

Provided these key information, the next design should beware of allowing children to make choices having an effect on the difficulty level of their tasks. Also, an element of surprise delivered in small ways through exploration has a positive impact on children. By no means, these surprises have to be large; it is the joy of finding something new that is so appealing.

4.1.3 Key Ideas for Memory Island
Since children with ADHD are particularly prone to getting bored easily (Hallowell et al. 2011) and losing their attention after seeing a pattern that they will usually recognize much earlier than others, it is necessary to come up with a feature(s) that would make the game highly diverse making the monotonous treatment methods somehow interesting. In order to combat the issue of the game-play becoming tedious too fast, a core feature of the new prototype is that it provides continuous variation through a procedurally generated, constantly changing game environment and content. The common factor for all the aforementioned serious games (including Lundelab's previous prototypes) aiming for the WM training is that the game-play consists of mini-games and hence does not form a cohesive experience. This important facet of the game emerged from one of several workshops with game developers and medical experts and according to a psychologist guest is more likely to attract majority of players. So this game's aim is to not provide the player with one training task after another but to make him or her feel that those are part of the game world and they all seem natural and fit together. One of Lundelab's requirements was to integrate adaptive difficulty which can possibly increase the diversity as well. Unlike most of the other WM training games, this one will push player to complete tasks in 3D environment while using simplistic visuals that has been popular among young children.

Mechanics-Dynamics-Aesthetics framework (MDA) was used to describe the prototype's design due to its clear connection between game design and development, game criticism, and technical game research, making the iterative process of developers, researchers and scholars clearer and stronger (Hunicke et al. 2004). Thus it should allow all parties to analyse, study and design solutions for design problems more easily. The design of the Memory Island prototype is described in the following three sections (4.2, 4.3, 4.4) and it comprises game aesthetics, dynamics and mechanics.
4.2 Game Aesthetics

The game prototype is set in a “cursed” or “crazy” island that constantly changes its appearance and content. Not only was this call motivated by the variety requirement discussed earlier, but the team also agreed on the theme due to its great potential in aesthetics of discovery, sensation, narrative, challenge and fantasy. The simple 3D visual representation should feel natural especially for the children familiar with Minecraft.

The sense-pleasure is then based on the attractive visuals of the environment and its content, but also by certain feeling of power gained by “magic” or “supernatural” ability which will be discussed more below (dynamics). The challenge lies in the actual discovery progress that depends solely on player’s ability to solve puzzles which are always on the verge of their abilities.

The fantasy aesthetics can also increase the attention of children and it has much to do with the future narrative. During the main game-play, the player travels via portals from one place to another. The child is given a “magical” ancient instrument and situated on a “mysterious” island; this could possibly result in players identifying themselves with the main character and thus capturing their attention for longer time.

In terms of meaningful game-play, the player is immediately given a memory task instructing him or her to find a treasure and open it by using memorized information. Hence the player soon see what the point of the game: apart from obvious memory training it is about treasure hunting (seek and collect).

The last but not the least important aspect of the game aesthetics will be some degree of competitive game-play. During the development including user testing with children (the following chapter), it was concluded that there has to be a game character posing a certain opponent to the child. This call was motivated by need of higher engagement coming from challenge but also from the way how this figure (= task) is represented to a child.
4.3 Game Dynamics

At the very beginning of the game, the player is provided with a “magical” artefact allowing him or her to control gravity of certain objects (stone cubes) and move them from one place to another (see mechanics for more detailed description). By using the underlying mechanics in the right way and understanding how they work, the player can fulfil various tasks or puzzles which—beside the obvious working memory challenge—requires paying attention. The player is to realize soon that the latter pays off in this game.

4.3.1 Main Game-play

The game itself is based on exploration of the mystical island; to do so, the player has to open closed portals leading to new locations. Various tasks work as obstacles standing in player's way and by solving them, the player is constantly trained (see Figure 4 for the entire process).

The training lays in working memory tasks that are the core of the game and are further described below. These tasks are flexible and their difficulty corresponds to player’s difficulty level which has to be always on the verge of their abilities.

To ensure intensive WM training, there is a time limit for completing each task as well as for wandering around the terrain and searching for treasure chests that can be opened only when remembering a combination of colours in the right order (keys) that is shown to the player during each loading of the game level. For most of the tasks, the player has only one attempt to finish it without the difficulty being decreased and white screen appearing as a result and gentle indicator of failure.

Due to certain findings from user testing (the following chapter), it has been decided to show the player his or her defeat but put emphasis on their victory. After completing any of the tasks, the progress is immediately indicated by gaining experience points (XP) and getting a gem reward. In some cases, the aforementioned portal is opened. The internal difficulty level does not correspond to the visible level shown to the player. The reason for this is that player’s motivation could drop very fast without seeing some progress out of trying. This way, the child is rewarded for success, but is not discouraged by losing any points. Instead the difficulty gets a bit easier and more doable.

The player must not be allowed to avoid a certain type of task, but he or she can usually choose one out of several based only on their preference.
Figure 4 Main Game-play
4.3.2 Working Memory Tasks

1. Treasure Chest Task

The player is given a sequence of three keys of different colours during the game loading (each transport to a different location). When the new location is loaded, the player has to find a treasure chest and use the memorized colour sequence to open it. It can some time to find it and player is motivated to explore the island while holding the information in his or her working memory.

![Treasure Chest Task](image)

Figure 5 Treasure Task (memorize, find, open)

This task aims for WM regarding colour and order, but also for updating this memory information, as the sequence changes with each location change.
2. **Deconstruction Task**

The player is standing in front of the closed portal (red colour). He or she is provided with a flashback vision showing him, in what order stone cubes of various colours fell down and blocked the portal. The main task of the user is then to remember this sequence and move the cubes out of the way (throw them into the fire) in the reverse order.

![Image of Deconstruction Task](image)

**Figure 6**  Deconstruction Task (memorize and throw into fire in the reverse order)

This memory span task aims for visual-spatial WM regarding colour and **order**.
3. **Maze Task**

The player is supposed to find a way out of a maze. The child is for a short moment provided with a 2D map showing a highlighted exit and then it has to follow its memory plan.

This task requires strong visual-spacial WM and spacial orientation. The emphasis is put on real-life situation transfer and therefore player cannot fail and neither is penalized when choosing an incorrect way. On the contrary, the development team agreed on the conclusion that it may be more universal, complex and realistic problem to solve when not remembering the entire way. It can be easily transferred into real-life situation and besides other things it strongly targets strategic thinking.

![Maze task (enter, memorize the map, find a portal in time)](image)

For that reason, the child is not penalized for choosing a wrong way. It is, however, limited by time and it is very unlikely that it can find the exit if totally lost. When the time is up a new game location will load.
If the child can find the exit in time, it is rewarded just like with all the other tasks, but the internal difficulty does not increase, as this is rather an extra task.

4. **Boss Task**

The player is exposed to a demon-boss figure who starts soon throwing cubes of various colours at him or her. The child has to react quickly and either jump aside to avoid the cube or throw it back at the figure and cause a damage to it, while remembering and updating the last two cube colours thrown by the demon.

This task uses N-back method, specifically 2-back and is very challenging in terms of WM as well as inhibition handling. The way how this task was designed is further explained in the following chapter.

Figure 8  Demon task (throwing a cube at the player)
4.4 Mechanics

4.4.1 Core Mechanics
Stone cubes of various colours are the most frequently used game objects working as a tool for solving various puzzles. These cubes are under influence of gravity and other laws of physics available in games. The “magical” item mentioned earlier is a base for most of the game mechanics. It allows the player to lift any stone cube up in the air and he or she can then choose a position where this still levitating object will move. This anti-gravity mode can be turned off and naturally the cube falls down thereafter. This can be applied to only one object at a time.

When the cube is lifted up, player can choose its new position in a simple way that precedes error made of inaccurate click of mouse, since the game is more about the idea and not about motor skills.

Some tasks do not require any manipulation with cubes. For instance, maze task has to be solved only by walking/running in the labyrinth. Similarly, in case of treasure chest, the player needs to find and walk towards a treasure chest and then open it by using the right keys. Demon task combines both: walking/jumping to avoid stone cube objects and the “magical” item to throw it back (anti-gravity).

The portals or other entrances simply pose the finale of one task and they are usually blocked until it is completed (the only exception is the entrance that was just used as the exit, so the player came out of it in the first place). By passing this entrance, player is given reward and feedback.

The current island location offers various tasks and the player can always choose one out of two or three to proceed with his or her exploration. There is a mechanism ensuring he or she have to do all types. The frequency of successfully completed task types is taken into account when generating new locations, so the utter avoidance to particular task is impossible. If there is one task being avoided for some time, next location will eventually contain two or three tasks of this type.

Details concerning the mechanics for each task are described further in the following chapter.

4.4.2 Advanced Mechanics
It was very important to choose right mechanics for the time limits in the game to make it feel more natural. Hence it was decided to stick to the classical elements and natural forces. When the time limit is reached (shown at the top of the screen), an earthquake appears apparently indicating the player his behaviour is not the one wanted. In case player did not complete any task at the current location and thus was just wandering around, he or she will be immediately transported to the task zone and will be forced to try a random task. In case player did complete at least one task at the current location, he or she will be transported to the new place (the terrain and tasks will be generated again).
There is also a time limit for the entire session duration which was set by 1 hour and is indicated by simple sunset. The player is informed that the game day is over and thus the session as well.

4.4.3 Game Progress

All the tasks are dependant on the internal difficulty level of the game that increases with player’s success to keep him or her challenged. Apart from this value used for adaptive difficulty, there are other indicators of player’s progress.

Player can see his or her level that increases with certain amount of experience points (XP) gained from successful completing of tasks. Naturally, for each level the required number of XP is higher and so it becomes more and more distant reward.

Apart from XP, player is after each success also given a gem which poses an immediate reward. The number of gems increases and the player’s collection gets wider. For each level-up the player gets and additional gem to stay motivated for levelling that gets more and more time-consuming.

The task difficulty varies and the reward in terms of XP as well:

- easy (reward: 25XP; tasks: maze)
- moderate (reward: 50XP; tasks: treasure chest, deconstruction)
- hard (reward: 100XP; tasks: boss)

One of the very challenging problems of this game design was making an effective and balanced system for the adaptive difficulty. It was repeatedly tested to find out if it gets harder too fast or too slow.

4.4.4 Task Selection

Three to four tasks are randomly placed on the island’s terrain based on the frequency of player’s effort to complete them. To prevent the player from avoiding certain tasks, a special mechanism has been made. When detected one task has been repeatedly avoided, the player is soon forced to do it, since the island will generate only the task of the unwanted type.

The treasure task is, however, always present and could possibly be executed more often than the others. On the other hand, it is randomly placed and sometimes steps in the other task zone which could force the player to do the other task first (due to the time limitations).
4.5 Early Stage of the Development Process

The development process of the game prototype was initiated in January 2016. The entire process took place at the Oslo based company Lundelab, and the team included both medical professionals as well as developers with previous experiences working on similar prototypes (described earlier). As previously mentioned, the main goal of the prototype was to convey exercises for visual-spacial WM training for children with ADHD. Not only did the prototype need to convey basic exercises, but it needed to do so in an engaging and motivating way in order to achieve a high rate of retention among the children using it. The company required an integration of at least one of the game mechanics to train working memory (SUT, n-back, spanboard, etc) and this prototype should have enough variety to last for at least 10 minutes per session. At the end it was put to the test by children with ADHD who were given a prototype to play with and thus train at home with parents.

4.5.1 Core Game Mechanics

After the second meeting, the team agreed on certain core game mechanics that will be used throughout the entire game. The player will be able to control gravity of certain objects (mostly of cubic character) and move them from one place to another. The user can relocate only one object at a time. After moving it to the correct position, the doors are open and the game level finished. The game controls are based on simplicity and based on common settings: player moves around by using arrows and the mouse is used to manipulate with the cube. By pressing left click on the cube, it is elevated. Then a light highlight appears on the floor and by another left click, cube moves that direction. By pressing right click, the cube falls. When falling on the pressure desk, the door is open and the player uses the exit. The game is over.

Since the entire game was supposed to be based on this simple mechanics, it was decided to implement this early prototype (Figure 9) as soon as possible and test it on children before moving to the next notch.

![Core Game Mechanics](image_url)
Four control children in this study target group (two of age 11 and two of age 13) took part in the testing session. Ethical considerations explained earlier were taken into account and formal testing protocol was set and used (appendix A). The aim of this test was to find out whether this basic puzzle task is understandable and whether the user interface is intuitive enough. It also should indicate us how children can cope with orienting themselves in 3D space and manipulating with 3D objects.

Children were given a simple task “play the game and try to solve the puzzle” while being observed and the screen was tracked. The following was tested:

- control the character by arrows
- select a cube
- move the cube to any position
- disable the anti-gravity by right click of the mouse
- place the cube on the button
- go through the doors that opened

The results (Appendix B: Table 1) and the post-play-test survey showed that the children were immediately able to understand what the “game” was about and apart from one individual they did not need any intervention in form of a hint. This one exception was provided with mere information that the right click of the mouse could be used as well. After obtaining this key hint, the child in no time completed the task with clearance but as well with joy out of the accomplishment.

All the children were satisfied with the controls and mechanics and they all claimed that they were intuitive to such an extent no changes should be done. They also agreed on the suggestion of showing hint text explaining the controls but only in case of a struggle after some time, since they perceived the finding how it works exciting. Based on those results, the proposed game mechanics will be used in an unchanged form, but some additional hints should be provided after detecting a struggle.

### 4.6 First Training Tasks & Adaptive Difficulty

After about a month of designing and developing the prototype, three tasks has been created (placement, deconstruction and maze; see previous chapter for details). The difficulty of those tasks is scaled gradually in accordance with player’s success or failures during the game-play. All the tasks are procedurally generated dependant on one single decimal value. To get a better overview and to get some values that could be used in building this adaptive difficulty training, in other words to obtain numbers that could lead to making game levels balanced, the development team decided to set up another testing session with children.

Again, ethical consideration were taken into account when making the second testing protocol (Appendix A). Six boys participated in the test (age 11, 10, 11, 10, 13, 13) which took place in informal settings in MD. Charlotte Lunde’s house. The children had six minutes for
each task and they were to progress as far as possible. Some had a possibility to continue for another four minutes to challenge themselves and to see how they can cope with harder game difficulty. When the time elapsed, they started with another task. Naturally, they were free to end the session at any point.

The results (Appendix B, Table 2, 3, 4) contain only the successful attempts, but with the exceptions of few cases, children did not fail at all. Only the six-minute-session data have been used.

4.6.1 Placement Task

The player is supposed to move stone cube objects on specific places. At first, for a short moment cubes are shown on their final positions. Then the player is provided with cubes and is to move them in a way that corresponds to his recollections.

This task aims for visual-spacial WM regarding colour, shape and position in 3D space. The order is of no importance here.

The placement task (Figure 10) was tested first and it appeared to be the most time-consuming task, as children got only to level 5 and the time needed for completing one level was higher than for the other tasks (Appendix B: Table 2, 3, 4). As they could not reach higher difficulty, it showed up to be the least popular task probably due to its static nature and easy difficulty.

After a little demonstration, most of the children understood what they were supposed to be doing. This task, however, required some interventions, as some children who seemingly understood showed in a while they actually did not. This task introduced more complex features, as from the level five children could also deal with merged cubes and the ice mechanics (allowing the to merge cubes).
4.6.2 Maze Task
The maze task (Figure 11) was tested as the second and it appeared to be the most popular task: six out six children chose it as their first choice due to its dynamic nature. They all appreciated the movement of the player and preferred it over the mouse clicking and manipulating with objects from the distance.

Some players were able to reach level seven (Appendix B, Table 3) and the task was by some criticized for its easy difficulty (three out of six had chosen it as the easiest task), whereas by others marked as challenging (regardless of age).

![Figure 11 Maze Task](image1)

4.6.3 Deconstruction Task
The deconstruction task (Figure 12) appeared to be the most straightforward and the most intuitive one. Apart from one exception, all the players understood that they were supposed to throw cubes into fire in the reverse order to the given one.

![Figure 12 Deconstruction Task](image2)
The first two levels of the deconstruction task were excessively simple featuring only one cube, hence no WM training was involved at that early stage. All the children, however, noticed a difficulty getting gradually higher and three out of six marked it as the hardest task. Note: the first level time was not tracked, as it was used for task demonstration only.

All the children found the given tasks difficulty balanced. Seven was the highest level reached by children and in case of placement task it was only five, therefore longer testing session is needed to see how they can cope with harder difficulties. The time given for memorizing the solution (task description) was sufficient and with exception of the maze balanced (too much time).

More findings:

- Player avatar is too short and the navigation is therefore troublesome when manipulating with cubes, because he or she has to look up to see where the cube currently is.
- Fire hole in the deconstruction task should directly burn the cube, thus the dropping it would be unnecessary, since the manipulation with cube is a bit clumsy and thus could be a distracting factor.
- It should be possible to skip the task description in the maze task, as the waiting can be at times too long, unnecessary and thus can result in attention loss.
- Some tasks are not difficult enough because of insufficient random physics “push”.
- All the younger children (under 13) wanted to continue in the current task after time elapsed, whereas the older ones immediately wanted to go ahead to other tasks.
- Players prefer dynamic tasks involving moving with player (maze) than static tasks based on clicking.
- Children liked the nature element aesthetics (ice in placement task, fire in deconstruction task).
- Children were satisfied with the graphics, as they found the aesthetics somewhat similar to those of Minecraft.

All the players were satisfied with the controls, as they seemed intuitive and similar to other games they had played.

4.6.4 New WM Task – Demon Boss

At the time of the last testing, it was known that at least one more task is needed—task that would be very challenging and hence effective but at the same time interesting and engaging to children. Based on the results of the test session, it was decided to make another dynamic task that requires player’s movement and makes use of classic elements (both of which has been very popular among tested children). Even earlier it was known that some task that would also target player’s response inhibition effective function was needed. Hence it was planned to implement a task that would pose a certain surprise for the player. A competition
is another truly important aspect to be implemented. In terms of medical effectiveness, it was convenient to make at least one more task using N-back tracking method explained earlier.

**Task description:** A monster figure challenges the player by throwing cubes of different colours at him or her. The sequence of the cubes is based on the aforementioned N-track, in this case 2-back method. The players always have to make a choice: they can either avoid the flying cube by moving around or they can catch the cube and it will be thrown back on the attacker. A little stress is involved here, as players have to react quickly. When being hit or trying to take the incorrect cube, they loses health; when choosing the right one and hitting the monster figure, it loses its health. Both the player and the demon have three lives.

### 4.7 Connectivity & Basic Terrain Generation

Until this moment, all the tasks were presented to the player separately and thus not yet giving an impression of cohesive game world. As the former half of the internship period passed, it was concluded that it was the time to connect all the tasks into one game and generate them accordingly to the environment that has generated as well.

In order to save some time, it was decided to use Cubiquity Voxel library for making a smooth terrain procedural generation (Figure 13). It was now possible to make mountains, caves and various terrain shapes from code in a rather fast manner not only regarding the implementation but also with regards to CPU performance. Based on the terrain size that is partially random, from two to three tasks are being generated and randomly placed in the terrain and respective number of paths is generated and the road leading to them built.

![Procedural Terrain Generation, up to 3 tasks to choose from](image)

By successfully finishing each task, a portal is opened (red light changed into green, Figure 14) and by entering it a new world is generated. The player can always choose which way he or she wants to go. Before the testing deadline, a simple mechanism preventing players from avoiding one type of task all the time was finished. This avoiding behaviour and its solution will be therefore tested as well.
During the team’s pre-Easter meeting, deadlines had been set for new testing sessions with control children but also the final testing with ADHD kids before the internship was over. Unfortunately, a week after, the other programmer left the team and thus the prototype had become a responsibility of only one developer.

### 4.7.1 Last Testing Session With Control Children

The 10th of April 2016, the last testing session with five control children (one of which had participated in all previous prototype testing sessions and two of them in one of the previous versions of the game) was executed. The session took place again in the informal settings of MD. Charlotte Lunde’s house and this time another MD doctor working with ADHD children for many years and having a lot of experience with children user testing participated and observed the process as well. The other developer who recently left the company agreed to help with this testing by his assistance during the entire process. Five boys (age 13, 10, 11, 13, 13) took part in the testing and had 30 minutes for entire session while of course being allowed to interrupt the game at any time. After 30 minutes they were given an opportunity to continue playing for additional 15 minutes of game-play just to see to how engaging the game would get.

The main goal of this test was to find out if the players find the game engaging and for how long it can attract their attention. The secondary aim of this session was to test out the new fourth task (demon N-back boss) that uses very effective working memory training method but could be potentially not intuitive enough. Previously introduced adaptive difficulty will be as well put to the test again. The children participating in the testing agreed on taking part in it voluntarily and their playing screen was recorded and they were briefly asked for complementary feedback thereafter (see Appendix A for the testing protocol).
4.7.2 Results

All of the children played the game for full 30 minutes. One of them later revealed that the game-play duration seemed too long for him, while one another wanted to prolong the session to beat the level score of other participants. The level shown worked as a temporary indicator of player's progress and should be replaced by other means, since players could see that it increased when successfully finishing a task but they as well noticed it dropped when they failed. This arose motivation in some, but marked frustration in others. Some children, however, did not pay attention to the level at all and were entirely focused on the game-play itself as they found it engaging.

Most of the children lacked of some further instructions at the beginning of the game and some were not even aware of the fact they could explore the island freely. Interestingly, some of them suggested a feature that had been already planned for another version of the game, namely adding some treasure boxes scattered across the terrain. This way there would be a clear goal and thus less of confusion among the players. One boy explained he would explore it if playing alone but not when competing with others, as it was apparently the main goal for him.

The first time introduced demon-boss-N-back task (Figure 15) appeared to be unanimously the most engaging one. Some children enjoyed it due to its challenging nature, the others because they simple deemed it fun. Similarly to the second most favourite task, the maze, it required player to move around but furthermore it was necessary to pay attention and react quickly. It was definitely marked as the most difficult task and some children pointed out that it was too much at the given level in comparison to the other tasks. Most of the players liked its simple Minecraft-ish appearance, yet there was a suggestion to add some more details, namely horns.

![Figure 15](image)

Figure 15 Demon-Boss-N-back Task
Unfortunately, the very basics of the task were mostly hard to understand and required explanation of the instructors in all cases. For some children it took a lot of time to actually beat it even when knowing how. However, it was observed that it, in fact, resulted in a great satisfaction when they finally did so. The text instructions given were ignored due to its too long content and undoubtedly the task had not been intuitive enough for players to understand on their own. Some players seemed to be confused after beating the boss, as there was no portal nor any visual reward which they aimed for, as they believed they deserve some for completing such challenging task. This applied for the older children.

We obtained especially interesting and valuable insight from a boy (10 years old) that participated also in the previous session and manifested signs of learning disorders and lack of motivation resulting from failing the game. As this is so typical for ADHD, it was important to pay close attention to his words and behaviour. Unlike the others, he struggled with understanding most of the tasks and he felt strong frustration due to failing and decreasing the level. He did not find them too hard to complete but too hard to understand. He enjoyed the most the dynamic tasks: the maze and the demon (regardless of his lack of success). The game-play time seemed to be too long for him, though this could be explained by an apparent motivation loss over time caused by strong frustration from constant level increase followed by immediate roll-back cycle. Unlike the older children, he was very interested in exploring the island and as all the others especially enjoyed jumping.

Most of the children found Placement task the most boring one, regardless of its marked difficulty at the higher levels, and it also caused some technical errors requiring an intervention. Furthermore, it took too much time to finish this task. The Deconstruction task seemed to be popular due to its easy nature, as some players tended to choose it over the others, because it increased their level fast. Finally, the maze varied the most in how its difficulty was perceived. While some considered it extremely easy, others deemed it very hard. All players found it very engaging regardless.

Other findings:

- The game controls were intuitive enough for most of the players to figure out on their own.
- Deconstruction task was still too easy and mostly the cubes do not collapsed.
- Most of the players never took time to actually explore the island, they usually went straight to the closest task.
- The older children were apparently much more goal-oriented, as they required some further rewards or visual achievement representation, while the younger ones appreciated the “fun” aspect of the game itself.
- The demon lives were visible, but not the lives of the player. Some players required to see how many lives they had.
- There were some visual remarks concerning demon’s appearance and the center of the screen point.

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4.7.3 Summary and Conclusions
The main conclusions based on this session are as follows:

- The level value revealing the adaptive difficulty mechanism behind the game should definitely not be visible to children, as it may put their motivation at risk. **Suggested solution:** Add an experience point (XP) mechanism and leveling in a positive fashion only so the children are rewarded by XP when being successful but not getting compensated in terms of score when failing.

- The demon-boss was the hardest but the most engaging task at the same time. The form was accepted positively by children, but it required thorough explanation by the instructors. **Suggested solution:** Short out the text description and provide a certain type of show-case, an example providing the sufficient explanation.

- The simplicity of the Deconstruction task is caused due to small amount of cubes at given level. On the other hand, this task was very easily understood and not particularly tedious unlike the placement task.

- The open world was greatly accepted by all the players, but they wanted some directions as well. Also, there was no time limit for wandering around and not doing the tasks. MD. Charlotte Lunde also pointed out that the intensity of the training should be higher and that too much of resting time should be avoided. The same issue seemed to have an impact on the maze task which provided players with no score increase nor with any time pressure. Regardless of being undoubtedly one of the most favourite tasks among children, some started avoiding it when knowing they cannot gain anything by completing it.

Another problem that arose due to technical limitations was long waiting time during loading each level. Consequently some of the players got bored, as they naturally found the long wait tedious.

Unfortunately, it was also discovered that one of the tasks, namely Placement task, caused crashes of the game and at the same time was apparently the least favourite one among the players. Since the final testing date was very close and the sole developer of the prototype had to implement a lot of changes all alone, it was decided to temporarily disable this task. However, this step can also mean a lack of memory training in the final prototype.

**Suggested solution:** Adding a new feature of treasure chests in the game had been already planned, but the results and conclusions raised out of the last testing provided much clearer idea about the form that could solve all the problems mentioned above.
4.7.4 Treasure Chest Solution
The waiting for portal transport (green lights loading) takes too long and thus the time could be used for another memory training. At the same time, the terrain walking is lacking some sort of goal. In order to resolve this issue, the loading time (which initially just had the player waiting for the game to load) was imbued with a WM training element: the memorization of a sequence of coloured keys that the player could later use to open a treasure chest hidden somewhere in the terrain. This treasure hunt gives another dimension to the terrain walking, but it also has to be limited by time in order to prevent the player from avoiding the main tasks or just spending too much time by unsuccessful searching. This creates some sort of light pressure that could motivate players to explore the island further while staying focused on the tasks.

It means that in the moment of launching the game, the player immediately starts doing tasks: he or she can, however, decide to not search for the treasure at all and instead try to solve some other WM challenge. The important fact is that he or she can no longer be completely passive and just wander around, as after time limit is reached an earthquake strikes to indicate their passivity. After that some other task is started.

4.7.5 Game Progress Representation
As explained earlier, real difficulty level should not be present visible to players. Instead they should be motivated to play longer and get better. To do so, a visual leveling system independent on the real internal difficulty level was introduced. It should work as a long-term motivation source to keep player interested in playing the game. The player is rewarded by XP when completing some task, but is not penalized when failing it. He or she is also given an immediate reward in form of gems that is same for each task (unlike XP that differs with task type).

4.8 Development Summary
Regardless of severe limitations in the development (only three months available with eventually only one active developer), the game prototype was created according to the design presented earlier, though it did not have all the features recommended (such as multi-sensory facilitation). The emphasis was foremost put on using experience from previous prototypes and attempting to develop WM game in strong connection of game and medical background. Once the game prototype had been finalized, the project progressed into its final evaluation phase, where participants from the real target audience of the game were included.
5 Results

This chapter deals with the results obtained from the final testing explained further in Chapter 3. Here, the results are presented, interpreted and eventually used to answer research questions.

5.1 Participants profile

All the six participants were children diagnosed with ADHD and their age varied from six to twelve years old. The participant group consisted of five boys and one girl. Two of them reported playing video-games every day, another two participants a few times a week and the last third playing a few times per month.

They were also asked whether they had played any other games that involved training before—four out of six answered affirmatively—and what they liked or did not like about them.

When asked about using computers, 50% of participants reported small confidence, one third good moderate and one subject did not answer. All the children admitted having stronger experience with tablets than with standalone computers. This finding might have had some impact on general playing experience, as using mouse and classical computer controls play an important role in the prototype game-play.

5.2 Play Time Comparison with the previous prototype

The tests of both the new and the previous prototype took place in almost identical circumstances. The only real variation between the prototype tests were the participant age (from eight to twelve in the old test) and the testing period (from 5th of June 2015 in the old test). The consequences related to this difference will be discussed below and in Chapter 6.1.

![Average Playtime Prototypes Comparison Over Days](image)

**Figure 16** Average Playtime Prototypes Comparison Over Days
The average playtime per day (Figure 16) was calculated from average week values gathered through the tracked logs for each player. Comparing the new prototype to the old one, the results (Appendix C: Table 5, 6) show that the players' average weekly play times increased by 46.75% from 13.06 to 19.16 minutes and the total amount of playtime increased similarly, by 46.72% from 479 to 702.8 minutes (Appendix C: Figure 20). The old prototype average play-time decreased from 16.67 to 8.67 minutes over six days, which makes it 48% drop. The new one decreased from 31.29 to 22.26, which means only 28.86% drop in playtime.

While the old prototype steadily became less interesting over time, the new one became quickly less played after the first day but seemingly managed to capture interest later. This apparent drop in play-time could be explained by simple fact that Norwegian holidays interfered in the middle of the testing session. Some participants admitted it may have effected their performance, as they could not pay attention to the game fully while being out of their common environment (e.g. camping). Another explanation could be that it took some time for players to actually understand the game tasks, as the reported difficulty score over time (Appendix C: Table 9) suggest so. Two tasks became considerably easier from the first day to the last one (60% decrease in the difficulty score), one decreased by 40% and only one task almost did not change (10% change in reported difficulty score). The measured overall success rate, however, does not support this explanation (Figure 19), as there is no apparent correlation between player's success and the overall play-time. Since patients with ADHD are in general poor self-observers, it is impossible to unanimously neither confirm or disprove it.

Regardless of the different trends in play time over days, it can be concluded that the new prototype was more successful in terms of total play-time, average play-time and a short term retention.

5.3 Motivation factors

When it comes to understanding what it is that motivated the respondents to keep playing, most of them reported that the act of exploring the game world was the primary source of motivation, closely followed by levelling. The element of exploration turned out to be the most frequently reported motivation drive for playing the game with levelling closely behind it. The other motivation sources such as gem collection, increasing their game proficiency, and task completion, ranked comparatively low by the participants (Appendix C: Figure 21).

5.3.1 Exploration

According to tracked game-play logs, the participants displayed interesting play behaviours when engaging with the game’s world and its narrative. Apart from one player, they all experimented and tried to jump into the water. Every participant tried to explore the island and several times experienced the earthquake. That supports self-reported interest in exploration from the questionnaire.

Furthermore, four out of six participants appreciated how the island was changing its appearance and all of them liked that they could always choose out of several tasks. One of the players complained about the earthquake.
Even though most of the participants were fond of *Minecraft*, only one out of six players liked how the game prototype looked. Probably, it was not because the prototype would not manage to emulate the art direction and style well enough, but rather because of the very resemblance to the popular game. Many tend to compare the Memory Island prototype to the mentioned game and lacked some more creative options, wider world and possibility to share the experience with other kids.

5.3.2 Gems
The tracked behaviour does not indicate any correlation between overall gems collected from the previous day and the overall play-time per day (Appendix C: Figure 22), neither do participants reported it had posed a significant motivation (apart from one exception). With closer look to each participant’s tracked logs, there was only one subject whose play-time appeared to be dependant on the gems collected. Unfortunately, due to the anonymous data nature, it was impossible to assign this individual to the one who selected gems as the main motivation in the questionnaire.

These findings could either mean that children with ADHD are not so interested in simple collecting based fast score gains or it should be designed differently. One participant suggested that rewards should be more variable offering wider scale concerning visuals (various treasures, staff appearance changes, etc.), while others required opening new game functions or options instead of mere visual or numeric reward. The latter leads again to the element of exploration related to narrative.

5.3.3 Level
Regardless of the visual level importance reported by the subjects, no connection between overall previous day success in raising level and the overall current day play-time was found to support it.

The specialist on ADHD with children, who took part in the introductory session, suggested that the levelling would probably played much greater role in players’ motivation if there was a way to compare their scores with each other.

This was of course impossible due to the signed consent and terms of anonymous data processing, but it is undoubtedly something that needs to be considered for the further development.
5.4 Tasks

5.4.1 Task Popularity
All the participants filled up the table with tasks saying whether they wanted to play it again or not (Appendix C: Table 7). They could choose one out of three options: yes (value 1), maybe (value 0) and no (value -1), so each task could score from -6 (the least popular) to 9 (the most popular). The maze task scored the highest (3), whereas the boss task the lowest (-1). This reported popularity correlates to the frequency in choosing the individual tasks (Figure 17).

The maze task scored the highest (3), whereas the boss task the lowest (-1). This reported popularity correlates to the frequency in choosing the individual tasks (Figure 17).

The captured player data corresponded well with the reported enjoyment of the tasks, as the players would more frequently play the maze and the deconstruction task over the treasure and the boss task (Appendix C: Figure 24). All the players requested more tasks and noticed its monotonous nature. That suggest they were able to detect the training pattern and hence more effort is needed to make tasks more variable and less tedious.

5.4.2 Task Successful Rate
A very strong correlation between task frequency and successful rate (ratio between successful attempts and all attempts) was found. The most successful tasks (maze and deconstruction) were also chosen the most frequently, whereas the least successful ones (boss and treasure) were a much less popular choice (Figure 18). XP reward might have played a role in task selection as well, according to tracked results (Appendix C: Figure 25), the smaller the XP reward value is, the higher frequency of task gets. It indicates that experience rewards probably did not matter in the players’ choice of tasks very much.
5.4.3 Task Difficulty

Five out of six participants filled up a table evaluating task’s difficulty over time (Appendix C: Table 9). They could choose out of three options for start and end of the testing period (first and the last day): 1) easy (-1), medium (0), hard (1), so each task alternative could get from -5 (easiest – 0%) to 5 (hardest – 100%) points. The reported difficulty end correlates negatively with the task frequency and the reported task popularity (Appendix C: Figure 26). This connection could indicate that participants tend to choose and preferred easier tasks over the difficult ones.

Even though the treasure task reported difficulty score ended as low, only two players were able to actually complete it, which is the same result as with the boss task. Only one player was motivated out of challenge, others preferred to choose the tasks they deemed the easiest. Five out of six participants did not perceive the game as a training and did not consider it tiring, but three children admitted it was very demanding concerning concentration.
5.5 Overall Success and Playtime

The results might suggest a slight positive correlation between average play time and average success ratio (Figure 19) and stronger positive correlation between average play time and average CTSR. This trend could indicate that children were to some degree more motivated when being comparatively successful in solving tasks. On the other hand, no positive correlation between success from previous day and overall playtime was found while using either of introduced success rate variables.

5.6 Other Findings

Four out of six children wanted to take part in the next testing to help with development of the game, but only one wanted to continue playing the current prototype; the others did not find it engaging enough. It was observed that children with ADHD in the tested group were considerably more open to criticize the game than children who participated in all the previous testing sessions. Another difference observed, was that contrary to control children, the participants diagnosed with ADHD did not complain about game difficulty being too low. Naturally, their impaired WM could be the explanation.
5.7 Summary

This section summarizes results in order to answer the research questions.

5.7.1 Research Question 1: How to make a serious game that will capture more attention of children with ADHD?

This question was simply answered by comparison of tracked play-time with the previous prototype. The main assumption in this study was that following game design methodical formal approach with recommendations from WM experts and guidance from designers working on the previous prototypes will result in higher overall play-time and in lower drop in play-time from the first day and the last day than in the previous prototype.

The overall play-time indeed increased (almost 50% improvement over the previous prototype) and the retention was higher (28.86% drop in play-time). These positive results can be credited to the merger of competencies of game development and medical professionals, as it was a necessary addition to the development process. The majority participants, however, did not want to continue in playing the game after the testing period.

5.7.2 Research Question 2: What motivates children with ADHD the most to play serious games?

This question was answered by qualitative research (questionnaire) with support of captured-player-behaviour logs.

The results of the final play-testing with children in the target audience showed that very few of them found the gathering of gem-stones to be motivating, and both data from the player tracking system as well as the data from questionnaires strongly indicated that gems had very little motivating potential. This means that WM training games for children with ADHD should either focus more on providing some intrinsic motivation (such as exploration or functional rewards) or come up with more elaborate extrinsic rewards to be successful when it comes to retention. It should be noted, however, that some types of extrinsically motivating rewards can be useful in certain contexts, for instance if they are coupled with a system where players can compare their score to each other. Furthermore, it is important to acknowledge that while most players did not find extrinsic rewards in the form of gemstones rewarding, one out of the six testers reported that they found it motivating. That also indicates that there is still some value in having extrinsic rewards in WM training games. If they can be added in a way that is unobtrusive to the players who are not interested in them, extrinsic rewards may be a cheap way of increasing retention for at least a small part of the target audience. The majority of the participants, however, required an interesting game-play based on exploration and did not pay much attention to the rewards. Thus, first of all, when developing WM game for such target group, it is necessary to concentrate on the interesting core game-play that is engaging without any additional external motivational support.

Of course, the real challenge lies in how to integrate the boring memory exercises and how to make them less monotonous and more entertaining while not being excessively difficult. The previous prototype finding that children with ADHD will prefer fast immediate rewards over those that are harder to obtain was confirmed. Indeed, all the participants admitted they
preferred an easy task over the hard one, with exception of one individual. This trend also corresponds to the negative correlation between reported difficulty of task in the first days (start) and reported task popularity. The participants were mostly choosing the tasks they were good at, which was supported by the strong correlation between task success ratio and task frequency that was discovered. This behaviour is contrary to the one observed in all the previous test sessions with children without any learning disabilities and could lead to better understanding of how to design games for children with ADHD. The progressive difficulty scaling has to be rather slower than fast, since none of the final test participants complained about tasks being too easy, but many players were apparently discouraged by too high difficulty of some tasks.

Contrary to this study’s initial assumption, the results showed that majority of participants did not like the way how the game looked, even though most of them found it familiar and similar to Minecraft. It might have attracted their attention at the beginning, but it also pushed them to compare those games. This effect turned out to be negative in the long run, as they expected something else and complained about the differences.

5.8 Participant Bias

It can be expected that under given circumstances of the test, player tendencies and “the final judgement” could have been biased. In spite of the fact the participants were told that their playing would help us with the research study and reassured that their role was important, it cannot change the simple fact they were pushed to play by their parents in their home environment. As if it was not enough that the game prototype probably had to compete with other games or other sources of engagement available at home, the timing of the test was utmost unfortunate due to the vacations.

One of the player’s encountered technical difficulties that prevented him from seeing the reached level and collected gems. Unfortunately, due to the anonymous nature of collected logs, it was impossible to find any correlation to his motivation tendencies and other behaviour.

In terms of task difficulty and its visual representation, it must be pointed out that some players were unable to understand certain tasks (mostly the boss or the treasure), which may have had an impact on the degree of them liking the game. Based on observations made, some children considered the game prototype boring only due to their lack of success. The very same player, who did not see the game progress statistics, was unable to understand the two mentioned tasks and never managed to complete them. He had the urge to overly criticize the prototype in front of the others and gave us some irrelevant suggestions for the future game changes. The present medical doctors later confirmed his opinion may have been seriously biased.

While some players had difficulty understanding tasks, some others had problems to understand the very point of the game—its meaning and concept. Some did not identify themselves with the game character, as they did not grasp its role (e.g. magician on the island) or did not see the whole picture (portals, changing island, anti-gravity, etc.).
6 Conclusions

6.1 Summary

The new prototype results show noticeably higher overall play-time and higher retention (lower drop in overall play-time from the first day to the last day) especially when taking into account its grave disadvantage concerning the period of testing struck by vacation. The aim of this thesis was not to create a perfect serious game prototype for children, but rather to come up with and test some potential ways in which WM training games can be designed, and to gain more knowledge about the player group plus provide future developers with this study findings.

In order to make the game prototype more engaging and long-term, the training pattern would have to be less apparent and more variable, since children with ADHD can look through it very fast. One convenient way how to do it has to do with another ADHD trait which is enhanced creativity. Regardless of whether the results of tests are applicable only to “Minecraft” players, it seems as a logical suggestion to integrate the creativity in training tasks or in the game rewards.

Another important thing that has to be concluded is that if the game is to be played in informal settings, the social aspect of the game is absolutely crucial. If the game has to compete with so many others, it either has to provide a multi-player mode or a way to compare results with other children. Without either competitive or collaborative social feature, it seems to be arduous to capture their attention for a long time. Even though one game task (demon) posed a certain competitive challenge, it ended up as the least popular and the least played task. Whether it was because of its difficult nature or not, players explicitly longed for some social (non-AI) features.

In terms of designing the training tasks, it is necessary to focus on understandability and very slow difficulty increasing. Unlike the control children, the children with ADHD did not lose interest in the tasks that seemed to be easy, on the contrary, they were repeatedly choosing the tasks they felt they were good at. Of course, it can be argued that the tasks have to be hard and challenging in order to be medically effective, but the key information here is timing. All the tasks should be very easy from the very beginning and getting harder slowly, so the testing can become a long-term matter.

6.2 Weakness of The Study

In terms of the prototype, there was not enough time (three months) nor enough people (eventually only one developer) to develop the game that would fulfill all the requirements mentioned in Chapter 2 and 3. For instance, some recommended principles from working memory experts were not applied (multi-sensory facilitation) and there was no time to prepare any narrative. The development limitations also resulted in insufficiently tested game and consequently in some in-game technical difficulties (bugs) that may have affected players’ performance and their overall impression.
Regarding the final test with children with ADHD and its results, it was very limited, as there were only six participants and the total duration of test was only six days. To have more precise correlations between measured variables and better insight in general, the study necessarily requires higher number of participants and tested days. Furthermore, the aforementioned unfortunate timing definitely took its toll on the test results.

What appeared to be a possible mistake was including the six year old individual in the test, as it showed lack of understanding to the game tasks and the questionnaire questions. At the end, it had to be concluded that the prototype requires older players than six years old.

6.3 Discussion

There is very little research done in the specific area that has been chosen to pursue in this study, but there is another master thesis (Karlsen, 2014) made in collaboration with the Lundelab company and referring to their previous prototype Mindcrafter. It also aimed for better understanding as to what motivates children to play working memory games, but it was not targeted on ADHD children specifically.

While that study suggested that children are attracted only by novelty and their play time (and thus attention as well) progressively decreased with time, this thesis did not confirm this trend in children with ADHD while using the new prototype. On the contrary, it seemed that after a very fast loss in popularity, it managed to capture players’ interest later. Was it because of more elaborately designed and developed prototype or because of the player group itself? To provide a definite answer to this question, further tests are needed, especially due to aforementioned circumstances of this thesis test.

The same study also concluded that familiar graphics resulted in an interest and excitement to play the game prototype among children, which is contrary to this study’s finding. It was discovered that game looks familiarity to successful off-the-shelf titles can be a “double-edged sword” for serious games, so to speak. Undoubtedly, it can make it much easier easier to capture the attention of players at the beginning, but it can also result in fast rejection of the game due to misplaced expectations. That is especially a problem when the serious game is to be used outside of formal settings (clinics, classrooms, etc.), as it essentially has to compete with all games that the audience is used to playing in informal settings (Berg Marklund, 2015). This issue could also have much to do with this study results showing that children with ADHD considered exploration as the most motivating factor to play. It is hard to say, whether they simply lean to this sort of motivation or whether it was out of the very resemblance to Minecraft and its most familiar type of game mechanics (e.g. exploration). Basically all the suggested changes fitted perfectly to what was different or was missing from the mentioned game: ranging from the very core of the game, where players lack of some creative mode or more places to visit, to the social aspect (playing with friends) that appeared to be crucial.
6.4 Future Work

First of all, there has to be much work done in the field of psychology, in order to understand better the player group and thus to be able to design games accordingly. But based on the results of this work, several ideas that could lead to improvement in engagement of WM training games for children with ADHD have to be recommended.

It may sound as a common sense, but a future study should try a different approach in the very delivering the game. Namely, parents should not be asked to push children to play, but instead give them the game in another less direct way. For instance, it would be interesting to see results of a study, in which children would not be obliged to play and the game would be given to them as a recommendation from other children. That has much to do with another conclusion of this study—the social aspect importance in serious games.

In order to make a WM game training effective, future developers should either make some simple form of multi-player that allows children to collaborate and play together or at the very least to make a table with score results allowing them to compare their progress. Of course, apart from positive motivation, it could also lead to the opposite, as these children tend to get easily demotivated and seeing others being constantly better could be a problem. Be that as it may, more research is needed in order to turn those assumptions into facts.

In terms of designing the game itself, future designers should consider making a game-play in correspondence with player’s mindset. It is probably also due to the enormous creativity levels in children with ADHD that they can see through patterns more easily, notice monotonous aspects of a game and get frustrated without insufficient motivation provided. It might be beneficial if another game attempted to turn this assumption to game-play’s advantage by integrating training tasks or other game features that would in a way challenge their creativity and provided them with tremendous variability. In that way the patterns could be less visible and thus less tedious for the players.

With regards to the game prototype further development, the emphasis should definitely be put on exploration, narrative and functional rewards instead of plain score if sticking to the current game looks. It is worthy of consideration to test the game in different settings including the formal ones and compare the results. In any case, in order to have some more insightful and solid results, it is imperative to carry out tests with much higher number of participants, for higher amount of days and in well considered time period.

Finally, it has to be noted that the most important question “What motivates the children with ADHD the most?” stays unanswered and is worthy of some future research. As long as the answer to this question is unknown, any designing or development of serious games for this group is rather experimental. Without experimenting, however, no progress would be ever made and this thesis brought us, at the very least, a step closer to understanding what direction all the interested people should be heading to find out. But even though the study have shown that there are certain tendencies and patterns that children with ADHD seem to share, and that slightly differentiate them from children without ADHD, future developers should definitely bear in mind that all groups of players are heterogeneous, and they cannot be treated as a unified entity that finds the same things engaging or motivating.
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Appendix A: User Testing Protocols

Session 1: User Interface & Core Mechanics

Introduction

The aim of this test is to find out to what extent the proposed game mechanics and the user interface are intuitive. The children participating in test agreed on taking part in it voluntarily and their playing screen will be recorded and swiftly asked for complementary feedback thereafter. This testing session will help to form the basic design for an upcoming game helping children with attention problems and other learning limitations.

Protocol

The children play the game separately regardless of each other and they are not provided with any instructions but “Play the game and try to solve the puzzle.”. Further encouragement is allowed, but without game system explanation with exception of the cases listed below. The instructor should be showing friendly, kind behaviour and during the test should be present only for documenting or special intervention purposes. Otherwise he or she should not interact with the child in any way.

Scenarios Requiring Intervention

(after 1 minute)

- Total inability to control the game (arrows and mouse not used)
- Inability to click on the cube

(after 3 minutes or 2 minutes since last intervention)

- Inability to move cube to another location (left click)

(after 5 minutes or 3 minutes since last intervention)

- Inability to press right click in order to drop the cube
- Complete inability to understand what is going on (either when the child is inquiring or it is apparent, in all other cases, this answer should be given “I cannot tell, you need to figure it out.”)

Note: All the interventions need to be written down but not in the presence of the children due to stress that could be raised this way.

If the player is for more than 10 minutes unable to finish the game regardless of provided hints, the instructor should intervene for the last time and end the game.

Complementary Questions

“Did you understand what is this about?”

“Did you notice that the door opened?”

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“Did you like the way how the game controls?”

“Would you appreciate different way of controls?”

“Generally speaking, did you like the game?”

“What else would you change?”

Note: children should be also checked whether it fully understand the question or not.

**Session 2: Adaptive Difficulty User Testing**

**Introduction**

Three game tasks (placement, deconstruction, maze) will be tested on children. The main goal of this test is to get some values that could be used in building adaptive difficulty training, in other words to obtain numbers that could lead to making game levels balanced. The secondary aim of this session is to find out to what extent the tasks and the user interface are intuitive. The children participating in test agreed on taking part in it voluntarily and their playing screen will be recorded and swiftly asked for complementary feedback thereafter. This testing session will help to form the basic prototype for an upcoming game helping children with attention problems and other learning limitations.

**Protocol**

The children play the game separately regardless of each other and they are provided with basic instructions how to solve the tasks. They are given each task for 6 minutes and then they get another one. At any point, the children can interrupt and end the session. The instructor should be showing friendly, kind and encouraging behaviour, but during the test should be present only for documenting or special intervention purposes. Otherwise he or she should not interact with the child in any way. The game screen is recorded and player’s results including time tracked and saved into a text file.

**Scenarios Requiring Intervention**

- Inability to control the game
- Inability to understand the task
- Serious bug in the game making further testing futile

**Complementary Questions**

“Did you find the tasks easy to solve?”

“Which task was the easiest?”, “Which task was the hardest?”

“Was the difficulty increasing too fast or too slow?”

“Was the time of task description enough to memorize the solution?”

“Which task did you like the most and why?”, “Which task did you like the least and why?”
“Would you appreciate different way of controls, did you find it easy to control the game?”

“Generally speaking, did you like the game?”

“What else would you change?”

Note: children should be also checked whether it fully understand the question or not.

Session 3: Task Connectivity + N-back Boss Task User Testing
Introduction

Four game tasks (placement, deconstruction, maze and demon boss) will be tested on children. This version of the game introduces automatic connection of tasks in self-generated game environment. This way the player explores the environment while coming across various tasks that are selected in a fashion preventing him or her from avoiding a specific type of the task. The main goal of this test is to find out if the players find the game engaging and for how long it can attract their attention. The secondary aim of this session is to test out the new fourth task (demon boss) that uses very effective working memory training method but could be potentially not intuitive enough. Previously introduced adaptive difficulty will be as well put to the test again. The children participating in test agreed on taking part in it voluntarily and their playing screen will be recorded and swiftly asked for complementary feedback thereafter. This testing session will help to form the basic prototype for an upcoming game helping children with attention problems and other learning limitations.

Protocol

The children play the game separately regardless of each other and they are provided with basic instructions how to solve the tasks. They are given 30 minutes of playtime in total, but in case of serious interest it can be prolonged by additional 15 minutes. At any point, the children can interrupt and end the session. The instructor should be showing friendly, kind and encouraging behaviour, but during the test should be present only for documenting or special intervention purposes. Otherwise he or she should not interact with the child in any way. The game screen is recorded and player’s results including time tracked and saved into a text file.

Scenarios Requiring Intervention

- Inability to control the game
- Inability to understand the task
- Serious bug in the game making further testing futile

Complementary Questions

“Do you like the way how the tasks were presented to you?”

“Did you like that you can always choose one out of several tasks?”

“Did you like walking the terrain?”

“Would you like to explore the island more?”
“Was it enjoyable to play the game all the time or did you find it boring? If so, when?”

“Have you found an interest in a specific task and wanted to repeat it several times in a row? If so, have you tried that?”

“Did you find all the tasks easy to solve?”

“Which task was the easiest?”, “Which task was the hardest?”

“Was the difficulty increasing too fast or too slow?”

“Was the time of task description enough to memorize the solution?”

“Was the time of task instructions enough to understand what you should do?

“Which task did you like the most and why?”, “Which task did you like the least and why?”

“Would you appreciate different way of controls, did you find it easy to control the game?”

“How did you like the demon boss task? Did you understand it quickly? Do you think it is understandable? If not what would you change or recommend?”

“Generally speaking, did you like the game?”

“What else would you change?”

Note: each child should be also checked whether it fully understand the question or not.
Appendix B: User Testing Results

Session 1: User Interface & Core Mechanics

Table 1 User Testing Results, Testing Session 1

<table>
<thead>
<tr>
<th>Arrows</th>
<th>Selection</th>
<th>Movement</th>
<th>Right click</th>
<th>Button</th>
<th>Door</th>
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<tbody>
<tr>
<td>100 %</td>
<td>100%</td>
<td>100%</td>
<td>75%</td>
<td>100%</td>
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</table>

Session 2: Adaptive Difficulty User Testing

Table 2 Placement Task Results, Testing Session 2

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<th>Level</th>
<th>Frequency</th>
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<th>S5</th>
<th>S6</th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
</tr>
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<td>12.3</td>
<td>5.5</td>
<td>18.3</td>
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Table 3 Maze Task Results, Testing Session 2

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<th>S4</th>
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</tr>
<tr>
<td>Level</td>
<td>Frequency</td>
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<td>S3</td>
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<td>-----</td>
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<td>2-3</td>
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<td>12.5</td>
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<td>6</td>
<td>4.5</td>
<td>7.25</td>
<td>4</td>
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</tr>
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<td>14.5</td>
<td>28.5</td>
<td>18</td>
<td>13.5</td>
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<td>14</td>
<td>16.58</td>
<td>11</td>
<td>28.5</td>
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<td>21.9</td>
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</table>
Appendix C: Final Session Results

Prototype Playtime Comparison

Table 5 Old Prototype Playtime Results

<table>
<thead>
<tr>
<th>Time (in minutes)</th>
<th>Day 1</th>
<th>Day2</th>
<th>Day3</th>
<th>Day4</th>
<th>Day5</th>
<th>Day6</th>
<th>Total</th>
<th>Average</th>
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<tbody>
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<td>Subject 1</td>
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<td>7</td>
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<td>19.00</td>
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<td>12</td>
<td>14</td>
<td>11</td>
<td>15</td>
<td>76.00</td>
<td>12.67</td>
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<td>11</td>
<td>78.00</td>
<td>13.00</td>
</tr>
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<td>10</td>
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<td>10</td>
<td>64.00</td>
<td>10.67</td>
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<td>79.00</td>
<td>90.00</td>
<td>68.00</td>
<td>52.00</td>
<td>479.0</td>
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<tr>
<td>Average</td>
<td>16.67</td>
<td>13.5</td>
<td>13.17</td>
<td>15</td>
<td>11.33</td>
<td>8.67</td>
<td>13.06</td>
<td></td>
</tr>
</tbody>
</table>

Table 6 New Prototype Playtime Results

<table>
<thead>
<tr>
<th>Time (in minutes)</th>
<th>Day 1</th>
<th>Day2</th>
<th>Day3</th>
<th>Day4</th>
<th>Day5</th>
<th>Day6</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
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<td>Subject 1</td>
<td>40.42</td>
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<td>23.03</td>
<td>0.00</td>
<td>28.43</td>
<td>32.66</td>
<td>146.46</td>
<td>24.41</td>
</tr>
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<td>15.49</td>
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<td>10.89</td>
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<td>12.03</td>
<td>20.19</td>
<td>81.53</td>
<td>13.59</td>
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<td>18.10</td>
<td>83.48</td>
<td>13.91</td>
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<td>8.54</td>
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<td>11.15</td>
<td>124.49</td>
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<td>18.33</td>
<td>10.93</td>
<td>12.86</td>
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<td>22.26</td>
<td>19.16</td>
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</tbody>
</table>
Overall Playtime Results

Comparison of the old and the new prototype

Motivation Factors

What motivated you the most?

- Exploring the game world: 4
- Collecting as much gems as possible: 1
- Increasing the level as much as possible: 3
- Becoming better at completing the tasks: 1
- Completing the tasks: 1

Figure 20  Overall Playtime Prototypes Comparison Over Days

Figure 21  Self-reported motivation sources
Figure 22  Correlation between gems and overall play-time

Figure 23  Correlation between levelling and overall play-time
Table 7 Reported Task Popularity Table

<table>
<thead>
<tr>
<th>Task/Participant</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>Total Score</th>
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</thead>
<tbody>
<tr>
<td>Deconstruction</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0 (50%)</td>
</tr>
<tr>
<td>Maze</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3 (75%)</td>
</tr>
<tr>
<td>Boss</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1 (41.67%)</td>
</tr>
<tr>
<td>Treasure</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>2 (66.67%)</td>
</tr>
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</table>

Figure 24 Task frequency

Table 8 Tasks Tracked Statistics

<table>
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<tr>
<th>Task</th>
<th>Frequency</th>
<th>Percentage</th>
<th>Success</th>
<th>XP reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deconstruction</td>
<td>176</td>
<td>26.75%</td>
<td>57.95%</td>
<td>50</td>
</tr>
<tr>
<td>Maze</td>
<td>226</td>
<td>34.35%</td>
<td>77.43%</td>
<td>25</td>
</tr>
<tr>
<td>Boss</td>
<td>123</td>
<td>18.69%</td>
<td>28.46%</td>
<td>100</td>
</tr>
<tr>
<td>Treasure</td>
<td>133</td>
<td>20.21%</td>
<td>25.56%</td>
<td>50</td>
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</tbody>
</table>

67
Figure 25  Correlation between tasks frequency and XP reward

Table 9  Reported Task Difficulty Over Time

<table>
<thead>
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<th>Task + stage / Participant</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>Total Difficulty Score</th>
</tr>
</thead>
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<td>Deconstruction start</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>1 (60%)</td>
</tr>
<tr>
<td>Deconstruction end</td>
<td>-1</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-3 (20%)</td>
</tr>
<tr>
<td>Maze start</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>1</td>
<td>2 (70%)</td>
</tr>
<tr>
<td>Maze end</td>
<td>0</td>
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<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-4 (10%)</td>
</tr>
<tr>
<td>Boss start</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>1</td>
<td>5 (100%)</td>
</tr>
<tr>
<td>Boss end</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>-1 (40%)</td>
</tr>
<tr>
<td>Treasure</td>
<td>-1</td>
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<td>-1</td>
<td>1</td>
<td>-1</td>
<td>1</td>
<td>-1 (40%)</td>
</tr>
<tr>
<td>Treasure end</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>-2 (30%)</td>
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</table>
Figure 26 Correlation between task frequency, popularity and reported difficulty
Appendix D: Final Session Documents

1) Request for participation in the research project
"How to make serious games for children with ADHD"

Purpose of study
The purpose of this study is to find out how to make better working memory training games for children with ADHD and provide some guidelines to their future designers. It is a master thesis called “How to make serious games for children with ADHD” and it is a part of “Serious Games” programme at University of Skövde in Sweden. The game prototype has been developed under supervision of both the university and the Lundelab company.

What will it involve for me?
The children and their parents will be first given a lecture from two medical doctors explaining working memory game essentials and providing guidelines how to use the game. Then the children will obtain it for 7 days to play it on daily basis and their playing tendencies (time spent, tasks selected and results) will be collected and send to our server anonymously. Each game session should take at least 10 minutes and is internally limited up to 1 hour per day. Finally, the children will participate in the last face to face meeting to answer our little questionnaire (up to 15 minutes) that will mostly deal with their motivation to play the game and their general impression.

The final questionnaire as well as the tracked data will be available for the parents and will not be used in the study if disapproved.

What will happen with the collected information about me?
All personal information will be treated confidentially, only the student conducting the research and the medical doctor founder will have an access to them. All the data used in the thesis will be completely anonymous and cannot be tracked back to the participant.

None of the participants will be named or identified in another way in the publication. Only anonymous behavioural data and the average age of participants will be used.

The participation begins with an introductory course in Monday evening, 2nd of May 2016. Then the final debriefing meeting will take place a week after—Monday evening 9th of May 2016.

Voluntary participation
It is voluntary to participate in the study, and you can at any time withdraw your consent without giving any reason. If you withdraw, all your information will be anonymous.

If you want to participate or have any questions about the study, please contact:

- Michal Krča (student conducting the research), tel: 48663674
- Charlotte Lunde (founder of the company, MD), tel: 91186072
- Björn Berg Marklund (thesis supervisor), tel: 0500-448351
Consent for participation in the study
I have been informed about the study and I am willing to participate

(participant’s signature, date)

2) Questionnaire
Age

<table>
<thead>
<tr>
<th>Never</th>
<th>Several times per year</th>
<th>Several times per month</th>
<th>Several times per week</th>
<th>Every day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

How often do you play video games?

I am good with computers.

<table>
<thead>
<tr>
<th>No</th>
<th>Not really</th>
<th>A little bit</th>
<th>Yes</th>
<th>Very good</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Did you understand that you have to do tasks to get rewarded?

<table>
<thead>
<tr>
<th>No</th>
<th>After a long time, yes</th>
<th>After some time, yes</th>
<th>Very quickly, yes</th>
<th>Yes, immediately</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Was it enjoyable to play the game all the time or did you find it boring? If so, when?

Did you feel that the game was training you?

<table>
<thead>
<tr>
<th>Yes, it made me tired and bored.</th>
<th>Yes, but I liked the tasks.</th>
<th>No, I enjoyed the game and did not perceive it as a training.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Do you think the training was too intensive? Did you need to rest?

| Yes, I could use some rest from the tasks in the game. | It was fine, I knew I was doing training, but I liked it anyway. | No, I did not perceive it as a training at all. |

Did you find it hard to concentrate on the game?

| Yes, it was hard to pay attention. | Yes, it was not easy. | It was ok. | No, I enjoyed playing without thinking about other things. | No, I totally lost track of time while playing it. |

What about the game motivated you the most?

| Completing the game challenges. | Becoming better at completing game challenges. | Increasing my levels as much as possible. | Collecting as many gems as I could. | Seeing more parts of the game world. |

Choose 1 or more options:

| Other: |

What do you think about the looks of the game?

| 72 |
Did you like that the island was changing?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Not particularly</th>
<th>I did not notice</th>
<th>Yes</th>
<th>Yes, it was great!</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Would you like to explore the island more? Why yes or why not?

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you like that you can always choose one out of several tasks?

<table>
<thead>
<tr>
<th></th>
<th>No, it does not matter.</th>
<th>No, I did not notice I can do that.</th>
<th>Yes, it was good to have a choice.</th>
<th>Yes, I liked it very much. It was fun.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Did you chose to repeat one of the game tasks several times? Why?

<p>| | | | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
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</tbody>
</table>

Would you like to play this task again?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>Maybe</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deconstruction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------</td>
</tr>
<tr>
<td>![Maze Image]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
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</tbody>
</table>
Was it difficult to understand any of the game tasks? Which ones, and why?

Which was your favourite task? Which was your least favourite task?

<table>
<thead>
<tr>
<th>Task name</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Green Thumb]</td>
<td>Most favourite:</td>
</tr>
<tr>
<td>![Red Thumb]</td>
<td>Least favourite:</td>
</tr>
</tbody>
</table>

Would you appreciate more tasks?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Maybe</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Action, puzzles, colour-matching, jumping, exploration or others?]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you like the way how the tasks were presented to you?
How would you rate the difficulty of the game challenges over time?

<table>
<thead>
<tr>
<th>First days</th>
<th>Easy</th>
<th>Medium</th>
<th>Hard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last days</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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How did you feel about the increase of the game's difficulty?

<table>
<thead>
<tr>
<th>slow (easy all the time)</th>
<th>fine</th>
<th>fast (hard very soon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explain:

What are your impressions from playing the game?

<table>
<thead>
<tr>
<th>Explain what and why</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

What did you like the most? What did you enjoy?

What did you like the least?

What should we change so you like it more?
Have you played any other training or learning games?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>If yes, what do you think made them better or worse than our game?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Would you like to play our game again?

<table>
<thead>
<tr>
<th></th>
<th>Not really</th>
<th>Maybe</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, never again.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, it was fun!</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Why?

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

Thank you very much for your time and attention!

Note: the questionnaire was translated into Norwegian due to easier and faster completion.