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„Exploring Computer Game Interventions for Children and Adolescents with Autism Spectrum Disorder“

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Ousama Ghessas, BSc

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Certification

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Abstract

Autism spectrum disorder (ASD) is a pervasive developmental disorder with an internationally estimated prevalence of around one percent of each country's population. In Austria, the approximate number of individuals living with ASD, including children, adolescents, and adults, is 87,000. Children with ASD also frequently suffer from comorbid medical conditions, such as anxiety and depression. Hence, identifying effective routes to treatment can be difficult because each individual with ASD may behave in different ways.

This thesis aims to investigate the needs, deficits, and preferences of children with ASD and how the barriers of this target group can be reduced through video gaming. The current state of relevant studies shows the effectiveness of video game interventions in helping children with ASD to improve their deficits in social interaction and communication and express their feelings, bearing the potential to enhance the integral well-being of this highly heterogeneous target group. Many of these interventions utilize serious games, but also entertainment games, virtual reality technology, or other technologies, such as robotics.

As part of this master's thesis, design guidelines for games targeted at ASD children were developed, as well as a roguelike video game that follows these guidelines. Furthermore, a user study with four participants was conducted that evaluated whether they perceived the roguelike game well and enjoyed it, keeping them further motivated to play. In addition, the participants' parents were asked about their assessment as to whether the game could be beneficial to their child.

Zusammenfassung

Die Autismus-Spektrum-Störung (ASS) ist eine tiefgreifende Entwicklungsstörung mit einer international geschätzten Prävalenz von etwa einem Prozent der Bevölkerung eines jeden Landes. In Österreich leben schätzungsweise 87.000 Personen mit ASD, darunter Kinder, Jugendliche und Erwachsene. Kinder mit ASS leiden häufig auch an Begleiterkrankungen wie Angstzuständen und Depressionen. Daher kann es schwierig sein, wirksame Behandlungsmöglichkeiten zu finden, da jedes Individuum mit ASS sich auf unterschiedliche Weise verhalten kann.

Ziel dieser Arbeit ist es, die Bedürfnisse, Defizite und Präferenzen von Kindern mit ASS zu untersuchen und zu erforschen, wie die Barrieren dieser Zielgruppe durch Videospiele reduziert werden können. Die aktuelle Studienlage zeigt die Wirksamkeit von Videospiel-Interventionen, Kindern mit ASS zu helfen, ihre Defizite in der sozialen Interaktion und Kommunikation zu verbessern und ihre Gefühle auszudrücken. Dies birgt das Potenzial, das ganzheitliche Wohlbefinden dieser sehr heterogenen Zielgruppe zu verbessern. In vielen dieser Interventionen werden Serious Games eingesetzt, aber auch Unterhaltungsspiele, Virtual-Reality-Technologien oder andere Technologien wie Robotik.

Im Rahmen dieser Masterarbeit wurden Design-Richtlinien für Spiele entwickelt, die sich an Kinder mit ASS richten, sowie ein Roguelike-Videospiel, das diesen Richtlinien folgt. Darüber hinaus wurde eine User-Studie mit vier Teilnehmern durchgeführt, in der evaluiert wurde, ob das Roguelike-Spiel für gut befunden wurde und es ihnen Spaß gemacht hat, so dass sie weiterhin zum Spielen motiviert waren. Außerdem wurden die Eltern der Teilnehmer nach ihrer Einschätzung befragt, ob das Spiel für ihr Kind von Nutzen sein könnte.

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Chapter 1

Introduction

Autism spectrum disorder (ASD) is a neurological and developmental disorder that is characterized by impairment in communication and social behavior. It is an umbrella term that describes a spectrum of heterogeneous disorders with a broad range of abilities and varying levels of severity. Therefore, each individual with ASD may behave in different ways, for instance, in terms of intellectual functioning, which may range from great impairment to remarkable levels. Also, language acquisition in many children with ASD is delayed, whereas in some it does not occur at all. Those affected often avoid eye contact with the other person and have difficulty interpreting gestures and facial expressions. In many cases, children with ASD frequently suffer from other comorbid medical conditions, including epilepsy, depression, anxiety, and attention deficit hyperactivity disorder (ADHD) [1, 2].

The percentage of children suffering from ASD has grown significantly over the recent years. According to the World Health Organization (WHO), the current estimated global prevalence of children having ASD is one in 160 (about one in 270 people). This estimate, however, varies from study to study; some have indicated even higher numbers [2]. The majority of prevalence studies were carried out in high-income countries and regions, such as northern Europe, Japan, and the United States, with the exception of China. There have been studies conducted in middle-income countries, but prevalence estimates are, for the most part, either unavailable or preliminary, especially in low-income countries [2, 3].

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), by the American Psychiatric Association (APA), published in 2013, reflects the current state of knowledge of neurological disorders and is widely used by clinicians and psychiatrists for assessment and diagnosis. The DSM-5 indicates that autism (a term often used interchangeably with ASD) is one of a range of pervasive developmental disorders, including Asperger's syndrome, autistic disorder, childhood disintegrative disorder, and pervasive developmental disorder-not otherwise specified (PDD-NOS). These diagnoses have since been grouped under the term "ASD". ASD is characterized as an early-onset disorder (before the age of 3) with deficits in social interaction, communication, and imagination, as well as restricted interests and repetitive patterns of behaviors [4].

Due to the aforementioned heterogeneous nature of ASD, there have been further attempts by researchers to classify ASD into different subtypes, namely (1) low-, medium-, and high-functioning autism and (2) regressive and non-regressive subtypes differentiated by the age of onset. 15-40 percent of children with ASD are affected by regressive autism. This disorder is characterized by normal development in the first 15 to 19 months, followed by regression that leads to loss of vocabulary, reduction in social interaction and responsiveness, and repetitive play behavior [5].

Further characteristics that individuals with ASD have difficulty with and are seen as examples of deficits in social communication and interaction are imitation, imaginative play, and nonverbal communication. These social deficits are most often manifested in terms of lack of reciprocity. For instance, many affected children find it difficult to share joy (e.g., showing a parent a new Lego construction) or to offer comfort to another person [6]. A prominent part of the nonverbal communication deficit is joint attention. Joint attention refers to the ability to focus one's attention on another person and an object at the same time, thus sharing interest in the object with someone else. In particular, eye contact, often in conjunction with pointing, and switching focus between the object and the person, plays a significant role [7]. It is considered a distinct difference between ASD and other developmental disabilities and a significant predictor of language development in children with ASD. Impairments in joint attention may therefore explain why language acquisition is delayed in affected children [6].

According to the DSM-5, it remains uncertain whether the apparent increase in prevalence of ASD is a result of changes in diagnostic criteria, improved awareness and assessment of the disorder, variation in research methodology of the studies, or a "true increase in the frequency of autism spectrum disorder" [4]. Nonetheless, it is important to identify effective routes to treatment, helping children with ASD to participate in the society they live in and acquire communicative and social skills.

1.1 Causes of ASD

Research suggests that functional discrepancies between regions of the brain may be linked to ASD [5]. Neurobiological studies deal primarily with cortical brain regions that are involved in speech and social perception, such as the neocortex. Especially the theory of "broken" mirror neurons has drawn attention in literature with respect to possible connections of ASD symptoms and impairments in the function of mirror neurons that can make it difficult for individuals with ASD to empathize with others [8]. It is hypothesized that dysfunctions in the mirror neuron system are the fundamental cause of individuals with ASD having emotional deficiencies and problems with imitating actions, which potentially lead to deficits in empathy and daily social life [9].

By contrast, recent data imply that subcortical structures (or deep brain structures) in particular, including the basal ganglia, amygdala, and cerebellum, play a crucial role in the development of functional brain and neurological disorders, as stated by Lecciso and Colombo [10] in a recent study. The researchers advocate a stronger focus on deeper brain structures and their role in developmental disorders such as ASD, as well as ADHD, considering that the first symptoms of ASD appear even before the cortex, which is not part of the subcortical structure, has fully matured. During this time, subcortical processes are dominant and control perception [10].

Studies of brain development suggest that the thickness of the cerebral cortex, including the areas that process visual stimuli, reaches its peak at age 11. The superior temporal lobe, which is involved in gaze direction as well as the interpretation of the actions and intentions of others, does not even mature until the age of 15 [11]. It is therefore unlikely that the developmental disorder becomes apparent at this point, but rather in early childhood. Jones and Klin [12] assert that individuals with ASD show deviations in visual attention and gaze behavior already at a very early age. In a study that tracked the development of eye movements in children within their first three years of life, both researchers found that 13 of the 110 infants studied who were later diagnosed with autism spectrum disorder still made frequent eye contact during the first weeks of life. However, between the ages of two and six months, the mean duration of eye fixation decreased significantly, which is a behavior not found in infants who did not develop ASD [12].

At this point in time, there are no clear biological causes for ASD. However, there is a lot to suggest that dysfunctions of subcortical brain regions play a crucial role in the development of neurodevelopmental disorders [10, 11]. On the contrary, the influence of the basal ganglia on brain development per se remains unclear, as studies on deep brain structures prove to be methodologically difficult since infants need to be examined to achieve reliable results [11].

1.2 Treatment Options

These days, there is a broad range of treatments available for children with ASD. Due to each individual with ASD having distinctive strengths and challenges, there is no universal consensus on treatment regimens. For this reason, not every affected person benefits from the same intervention. Approaches for autism treatment include applied behavior analysis, occupational therapy, the use of assistive technology (such as neurofeedback), and dietary and alternative medicine approaches.

1.2.1 Applied Behavior Analysis

Applied Behavior Analysis (ABA) is the intervention method with the most empirical support for its efficacy. It is a behavioral approach that aims to improve social interaction and communication and reduce negative behaviors by positive reinforcement [13]. Positive reinforcement is used to provide early focus on imitation, (joint) attention, motivation, and compliance. ABA systematically teaches small and measurable units, helping build complex and adaptive skills in children. Also, this therapy method is designed to teach children through intensive and reinforced practice and is individualized for each child [14].

Lovaas, a Norwegian researcher, was the first scientist to use the principles of behavior therapy intervention for the therapy of children with ASD, starting in the 1960s, and invented ABA interventions to mitigate challenging behaviors and establish communicative language [15]. The first program developed in 1973 by Lovaas and colleagues that utilized this technique was the Young Autism Project (YAP), which was mainly applied to preschool children [13, 15]. This intensive, structured behavioral program aimed to provide 30-40 hours per week of one-on-one instruction for children with ASD. Lovaas justified this decision by saying that children with ASD should have 40 hours to learn, to have the same learning opportunities as typically developing children who learn all day every day [15]. A long-term controlled assessment of the program yielded that 47 percent of the treatment group achieved normal intellectual and educational functioning, compared with only two percent of children within the control group, who received a non-intensive ABA intervention 10 hours a week [16].

However, there is also criticism of these studies with regard to outcome measurement, which included IQ scores and school placement. For example, the study participants were not randomly assigned to groups, which could have had an influence on the observed differences. Furthermore, it was suspected that the study participants had high-functioning autism, which would be a possible explanation for the high IQ scores [13].

1.2.2 Occupational Therapy

Occupational Therapy (OT) employs various services and techniques for training individuals with ASD of all ages to improve their living standards (e.g., by promoting health and preventing or living better with illness and impairments). This is accomplished by focusing on engagement in daily living activities, such as feeding and dressing oneself, as well as following safety procedures and participating in recreational and social activities. OT therapists initiate their sessions by evaluating the specific individual's strengths and challenges during daily living tasks. Afterward, an individualized intervention process takes place, which is based on the results of the evaluation step and intends to help the patient develop or improve occupational engagement and social skills. The final phase involves the measurement of outcomes. The therapist assesses whether the patient's occupational performance, overall satisfaction, health, and wellbeing have improved [17].

1.2.3 Neurofeedback

Neurofeedback, also known as neurotherapy or neurobiofeedback, is a special form of biofeedback designed as a computer-aided technique to help with dysregulated brainwave patterns [13]. In neurofeedback applications, the electrical activity of the user's brain is measured and recorded by an electroencephalography (EEG) headset, which then feeds this information back to the user in real-time through visual and/or auditory stimuli [9, 13]. The user is able to associate their current mental state (e.g., state of attention) with changes on the neuronal level [18]. For instance, if the amplitude of the brain signal is kept within a certain threshold (which is often predefined by a trainer), the user is rewarded with positive feedback that may include in-game scores or a visually pleasing image [19, 20]. In this way, a learning loop is created, letting the brain find the optimal state on its own [19].

During a neurofeedback training session, which typically lasts between 20 and 30 minutes, the electrodes of the EEG are placed on the user's scalp or different areas on the head, such as the earlobe(s). Symptoms of headache or tiredness may arise if a session lasts longer than 30 minutes [20].

Neurofeedback has become an emerging field of interest in autism therapy. The underlying theory is that neurofeedback training can help normalize the mirror neuron system and hence regulate the mu rhythm [9]. Mirror neurons play an important part in cognitive processes, including imitation, language, and empathy. They are activated during observation of a movement or if an execution of a movement is made [21]. The mu rhythm describes brain oscillations between frequencies of 8 to 13 Hz and is related to mirror neuron activity [9, 22]. In typically developing individuals, mu waves are usually suppressed when they perform motor actions as well as when they observe others performing motor actions. Mu wave suppression is also linked to higher social information processing, including social skills. On the contrary, patients with ASD did not show mu suppression to observed movement in past studies, resulting in the presumption that these individuals' mirror neuron systems might be altered.

However, there are also studies that question and are critical of the mirror neuron system theory, arguing that they could not discover differences in mu suppression to observed movement between individuals with ASD and typically developing individuals [9].

Aside from the standard EEG technology, the empirical concept of quantitative EEG (qEEG) has been established, which is a diagnostic evaluation tool for defining anomalies in brain function [13]. qEEG employs mathematical and analytical techniques to convert the raw brainwave data into various frequency subbands, such as delta, theta, alpha, and beta [19]. Figure 1.1 exhibits an example of a qEEG analysis performed on an adolescent female patient with an Asperger syndrome diagnosis before (top line) and after neurofeedback (bottom line). The green areas are associated with regular brain activity, whereas colors other than green specify brain activity that deviates from the norm. Due to the conducted neurofeedback therapy session, neurophysical changes were happening in the brain.

These changes were linked to improvements in the patient in terms of increased attention, emotional control, and social skills [13].

The first case study of neurofeedback on a child with ASD was carried out by Cowan and Markham in 1994. A qEEG analysis was performed on the eight-year-old child, and it was observed that the activity of alpha (8-10 Hz) and theta waves (4-8 Hz) was abnormally high, primarily in the parietal and occipital lobes. After undergoing a neurofeedback protocol with 21 sessions, the findings noted that autistic behavior per se improved (i.e., less giggling, spinning) and also social functioning in everyday life [5]. Other studies also yielded improvements in cognitive flexibility and social behavior [23, 24, 25, 26].

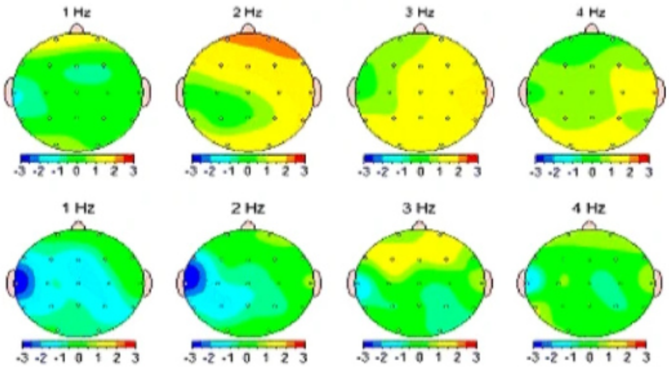


Figure 1.1: The top line shows a qEEG before neurofeedback, the bottom line a qEEG after neurofeedback.

1.2.4 Diet Treatments

Some studies [27, 28] have suggested that individuals with ASD may have issues digesting the proteins in foods containing gluten (e.g., wheat) and casein (dairy products), causing excessive opioid activity in the brain. Therefore, researchers have hypothesized that a diet free of gluten and/or casein could help alleviate the symptoms of ASD. Hyman et al. [29] have compiled a double-blind, placebo-controlled study assessing the efficacy of the gluten-free/casein-free (GFCF) diet on child subjects with autism. 14 children between the ages of three to five years participated in the study, who were put on the GFCG diet for 12 weeks, and continued on the diet after the study for another 12 weeks. The subjects were given either foods containing only gluten, only casein, both gluten and casein, or a placebo. The researchers could not draw any conclusive evidence for the impacts of the GFCF diet on measures of physiologic function or other behaviors typical for ASD. However, it is claimed by Hyman et al. [29] that their findings should be assessed with caution due to the small sample size of the study. A study carried out by Johnson et al. [30] came to the same conclusion that there was no evidence of the GFCF diet being beneficial for reducing symptoms of ASD.

On the contrary, the findings of Knivsberg et al. [28] showed significant improvements in autistic behavior and motor problems in 10 children with ASD on the GFCF diet. It is assumed in [29] that the positive outcomes of [28] may be due to the study being a one-year trial. The participants received other interventions besides the study, as Knivsberg et al. [28] did not keep track of accompanying treatments. As the study results were gathered through reports of the participant's parents, who were aware of whether their children were sticking to the GFCF diet or not, this might also be a reason why the results were positive.

Having rigid control over the diet of these children is an apparent restriction of this kind of treatment. Moreover, parents may not know precisely which foods should be restricted in such a diet. Due to each child being physiologically different, potential effects may occur either sooner or later depending on the child [13].

1.2.5 Nutritional Therapies

There exists a diverse range of approaches to complementary and alternative medicine (CAM) to treat symptoms of ASD, including the supplementation of melatonin [31], l-carnosine [32], vitamin D [33], and omega-3 fatty acids [34]. However, besides melatonin, there are only very few controlled trials on the effects of these nutrients. Gagnon and Godbout [31] conducted a literature review that looked into the potential effects of melatonin on the symptoms of individuals with ASD. In autism therapy, melatonin is primarily used to treat sleep problems, though it has also shown to have an effect on other symptoms such as anxiety, depression, and gastrointestinal problems. These symptoms often appear as comorbid medical conditions associated with ASD. Results outlined that studies confirm the potential of melatonin to help with anxiety and gastrointestinal issues. Consequently, Gagnon and Godbout argued that future research should focus on melatonin as a therapeutic means for comorbid symptoms of ASD [31].

The effect of L-carnosine supplementation was researched by Chez et al. [32] in a double-blind, placebo-controlled study on autistic children. L-carnosine is a naturally occurring semi-essential amino acid mainly found in brain and muscle tissues in higher concentrations.

31 children (between three and 12 years of age) were given either a dosage of 400 mg L-carnosine twice a day or a placebo for a period of eight weeks. Children treated with L-carnosine exhibited significant improvements in behavior, socialization, and communication [32].

Posar and Visconti [34] discussed in their case report that a deficiency in omega-3 fatty acids, especially beginning from childhood, may have a negative influence on brain connectivity, neuro- and synaptogenesis, and potentially causes inflammation. Cannell [33] reported that the notable global increase in prevalence of ASD may be related to vitamin D deficiency, which is particularly more common in urban than rural areas, mainly likely due to sun avoidance and being exposed only to low UVB light. Mazahery et al. [35] carried out a randomized controlled trial investigating the effectiveness of both vitamin D and omega-3 fatty acids in the remedy of irritability and hyperactivity symptoms in children with ASD. 111 children with ASD (between 2.5 to 8 years of age) participated in the study, where 73 of them were involved until the end. After 12 months, results concluded that the treatment with either or both nutrients led to significantly reduced irritability and hyperactivity. It should be noted that there was yet a slight increase in irritability in the group that received the placebo. Mazahery et al. [35] assert, though, that those who dropped out of the study showed more pronounced symptoms of ASD than the other participants, potentially diminishing the results of the study in this regard. Nonetheless, according to the study results, both omega-3 fatty acids and vitamin D bear the potential to improve the irritability and hyperactivity symptoms in children with ASD.

1.3 Technology as a Means of Intervention

There have already been several computer-based gaming interventions for the purpose of treating children with ASD in the past years, including games for improving emotion and face identity recognition abilities [36, 37]. Such kinds of games are generally described as serious games. A serious game is a digital game not primarily and exclusively designed for entertainment purposes but also for a variety of other fields, including health, education, or skill enhancement [38]. Serious games have drawn increasing attention in the healthcare area, bearing the potential to improve the well-being of children and young adolescents as well as being beneficial in mental health interventions [36, 38, 39]. They have also been regarded as a cost-effective and accessible form of intervention for young people with ASD [40].

Approaches to combining serious games with virtual reality (VR) technology also exist. Virtual reality environments are proposed to help individuals with Asperger's syndrome reduce their social problems [41]. Furthermore, they may provide a safe environment for therapy sessions by having control over how sensory information is conveyed and presented to the patient [40].

Apart from computer games, there have also been studies using technology-aided interventions for individuals with ASD, such as the use of touch-screen mobile devices by people with developmental disabilities [42] and tablet computers and portable media players as speech-generating devices [43]. Research examining the effectiveness of these interventions has been done increasingly over the last few years, where meaningful improvements in social interaction and communication skills could be observed [44].

1.4 Research Objectives

One research objective of this master's thesis is to explore the effect of technology- and gaming-based interventions on children with ASD, showing that video games per se may assist in fostering socialization and friendship, while also investigating their needs, deficits, and preferences. Further, it aims to evaluate and define a design framework for use in developing computer and video games targeted at children and adolescents with ASD. A second objective of this thesis is to present a proof-of-concept video game that is built upon this framework that has been played by children and adolescents with ASD, revealing whether it was well received and enjoyed by them over a period of two weeks. The thesis also aims to explore the potential benefits of the game for the child or adolescent by asking both parents or one parent of the participant about their views in this regard.

Chapter 2

Literature Review

This chapter looks at the available literature that addresses the potential effects of computer and video games on young individuals with autism spectrum disorder. In particular, several types of technology-based interventions conducted by the reviewed studies are examined. These interventions either utilize serious or entertainment computer games, virtual reality technology, or other technologies, such as robotics. Also, this literature review aims to investigate the needs, deficits, and preferences of children with autism spectrum disorder and how the barriers of this highly heterogeneous target group can be reduced by means of technology and, particularly, video gaming.

There has been much research devoted to this area, especially in the serious games sector. Though not without potentially negative aspects, a lot of literature shows the effectiveness of video games in helping children with autism spectrum disorder to improve social interaction and express their feelings, bearing the potential to enhance the well-being of this target group altogether.

The literature review was conducted by searching multiple electronic databases, including IEEE Xplore, Semantic Scholar, ScienceDirect, PubMed, and Wiley Online Library, on the search terms "autism" OR "autism spectrum disorder" OR "ASD", "gaming" OR "computer game" OR "serious game", "interventions" AND "behavior". Each of the search terms was identified in accordance with their appropriateness and relevance within the context of this literature review. They were combined in different ways to narrow down the search result as much as possible and obtain the most appropriate articles. While there was a preference for articles having the most recent publication dates from 2016 onwards, some older sources were found using the snowballing [1] technique. These sources also contain viable information and establish foundational concepts that continue to this day. In addition, articles that discuss technology-aided (not explicitly gaming-based) health interventions in general were also included due to them being theoretically aligned with the purpose of this literature review.

After taking these factors into consideration, the actual data in the articles were analyzed. The sources were evaluated with the following criteria:

1. Do they provide comprehensive case studies on gamified interventions?
2. Do they describe an approach for a design framework for games targeting children with ASD?
3. Is the information provided in the literature based on other research?

2.1 Entertainment Game Interventions

Flood [44] conducted a study exploring the social behavior during video game play of young adolescents with ASD. The participants of the study, 13 in total, were divided into two groups (ASD and non-ASD), with five participants in the ASD group and eight participants in the non-ASD group. All five ASD adolescents were male, whereas within the non-ASD group, six were male and two female. Moreover, the average age of the male participants was 31, and that of the female participants was 21. Thus, the subjects did not consist of children for the most part.

The game *Fortnite* was played for 40 minutes by the two groups, while each group was video-recorded and the gameplay captured. To examine the social behavior of the participants and compare it with the corresponding other group, various variables were measured, with the most worth mentioning being (non-)reciprocal communication, expressions of happiness and excitement, number of aggressive acts, delay of social interaction, and distraction. Reciprocal communication was measured by observing how often a player responded to another player during play through word, action, or laughter. Non-reciprocal communication, on the other hand, means how many times a proband did not respond to another player when the opportunity was given during the game to do so. Happiness and

[1] Snowballing refers to the process of gathering literature through the reference lists in the articles.

excitement were defined by how often a participant while playing the game, went into a state of these emotions and expressed them through words (both appropriate and inappropriate word choices), body language, or other gestures and facial expressions such as laughing or smiling. Potential aggressive acts were also considered a variable for the study; it was measured whether the probands displayed verbal or physical aggression during game play, including the use of vulgar and improper words, either towards the game itself or the other players.

The variable "delay of social interaction" was defined by how often a delay of three seconds or more occurred when another player started to interact with the participant, whereas the distraction variable is a measure of how many times a proband looked away from the computer screen or keyboard.

[44] yielded results in so far as there were differences in the period of time both groups spent playing *Fortnite*. The ASD group played slightly more than half the amount of time the non-ASD group played the game. Furthermore, the researcher observed that three ASD subjects preferred to play with themselves, whereas the same counts for only one non-ASD subject. This supports the conclusion that the difficulties in communication and social interaction of individuals with ASD in the real world can be translated to the virtual world in a sense that they prefer to play with themselves.

Concerning the results of the several defined variables, the ASD group turned out to be more engaged with reciprocal communications than the typically developed (TD) individuals from the non-ASD group. In fact, the amount of communication was more than double (a mean of 6.2 vs. a mean of 2.6) compared to that of the non-ASD group. However, in terms of non-reciprocal communication, the ASD group completed less than the non-ASD group, which was a surprising finding to the researcher, who originally predicted the opposite to happen. On the variable of the number of aggressive acts, the research resulted in a mean of 0 for the subjects with ASD, meaning that they never showed any trace of aggression during game play. The non-ASD group had a mean of 0.6 in that regard. It is worth noting, though, that the ASD individuals turned out to be more annoyed or frustrated with the game. The researcher assumed that the reason for that might be due to the higher levels of emotional sensitivity that they show occasionally. Nevertheless, the amount of annoyance and frustration was comparatively small.

The ASD group showed fewer expressions of happiness and excitement than the non-ASD group (a mean of 5.4 vs. a mean of 6.9), albeit both measurements were on the lower end. On the final two variables, delay of social interaction and distraction, it can be said that there was not any delay measured (meaning that there either was communication going on between the groups or not), and the ASD subjects were less distracted in comparison to the non-ASD subjects. The researcher was not surprised at the low amount of distraction shown by the ASD group; possible reasons for this finding might include the stronger aptitude individuals with ASD have for focusing on tasks, or they simply wanted to do well in the game.

The main weakness of this study includes the small sample size consisting of five subjects in the ASD group and eight subjects in the non-ASD group. The researcher argues, though, that this kind of research has not been done before, eventuating in these limitations. This research is seen as the first step in deepening the knowledge on the comparison of the social behavior of ASD individuals with those without ASD in the context of a virtual environment [44].

A survey conducted by Sundberg [45] examined the correlation between online gaming and loneliness and/or friendships, with the target being individuals with ASD. In addition, various examinations in terms of video gaming per se were carried out, including how many hours ASD and non-ASD individuals spend every day playing video games and what effect this has on the feelings of loneliness and quality of friendships. The survey results yielded that the participants diagnosed with ASD play significantly more video games than the control group, which was made up of participants with typically developed adolescents and adults. Moreover, the individuals with ASD showed a stronger leaning towards playing online games than those without ASD as a tool to escape from reality. In terms of friendships, the probands with ASD who play online games turned out to have remarkably more friends than those who do not play. This tendency could not be observed within the control group; no notable differences were found.

Further findings show that the ASD participants who play less than one hour a day go through significantly less loneliness than those who play up to five hours a day, but not less than those who do not play at all or those who play more than five hours a day. It is hypothesized by the researcher that probands who comparatively play less frequently can gain benefit from being able to cultivate both online and real-life friendships. On the other hand, those who play more than five hours a day may have restricted real-life interactions and thus fewer issues building closer friendships online due to spending more time interacting with fellow players. However, all in all, the results in [45] indicate that online games may help individuals diagnosed with ASD build and sustain relationships and decrease feelings of loneliness.

Because the study is cross-sectional, there arise a few limitations regarding the research. It is not certain whether more friendships lead to online gaming or if online gaming leads to more friendships. In addition, there was no actual diagnostic proof of the participants of ASD. Hence, it is possible that non-diagnosed ASD individuals were part of the non-ASD control group.

It is also not evident if the study results can be generalized to the larger group of individuals diagnosed with ASD. Since the participants of the study were enrolled via email and social media sites, there is a higher likelihood that individuals who are more familiar with these online platforms also play online games and engage in online socialization than those who are not familiar with these platforms. Lastly, the sample size of ASD non-gamers as well as non-ASD non-gamers was comparatively rather small, additionally limiting the generalizability of the study [45].

Finke et al. [46] conducted a study in which the behaviors of children with ASD playing video games were analyzed, including the parental point of view on video game play. The evaluation method of the study comprised collecting surveys from parents of the examined children between the ages of 8 and 12 years. 152 cases were included in the final data set. The researchers found that children with ASD play video games. However, there was no significant correlation found between the time, intensity, or type of game played and the severity of the children's ASD symptoms. Results also concluded that parents generally approve of video games for their children diagnosed with ASD. Furthermore, some parents also showed a positive inclination towards video game play being beneficial for their child's development [46].

Indeed, as stated by Durkin et al. [41, p. 81], "individuals with ASD are strongly attracted to screen-based entertainment, including interactive, virtual reality displays and video games". Durkin et al. [41] assert that video game play can be appealing to adolescents with special educational needs, including those with ASD, in a sense that video games per se are intrinsically very motivating. On the one hand, the authors claim that video games are challenging: they often involve logic, demand knowledge of cause and effect relationships, and navigation skills. However, some children with ASD may have particular superior abilities in these regards, allowing them to perform well in video games [41].

Durkin et al. [41] also looked at the motives of children and adolescents with ASD for using screen-based media in their study. They concluded that these could have a positive effect on specific abilities, especially social ones. Screen-based media can help them feel socially accepted. This may also be why children with ASD are attracted to video games. It is a matter of exchanging ideas with peers who are also interested in video games or developing a sense of belonging [41].

A well-cited study by Kuo et al. [47] of 52 adolescents with ASD demonstrated the correlation between friendship quality and activities in which they often engage with friends. Playing with video games was a preferred activity of the male participants, emphasizing that those who played video games with friends on any given day reported more positive friendship qualities with their best friend compared to participants who did not play video games with friends.

Mazurek and Engelhardt [48] designed a study to assess the relationships between video game playing and problem behaviors among adolescents with ASD. The subjects of the study consisted of 169 male boys between the ages of eight and 18. The data were gathered through parents who reported on their adolescent's behavioral status, video game use and preferences, the preferred video game genre(s), the average number of hours playing video games per day, and any problematic video game play patterns such as showing addictive behavior.

Table 2.1 exhibits the video game preferences of the subject children. The most frequently reported video game genre as the first choice was the Action category, succeeded by Platform and Shooter.

The research results concluded that there was no significant correlation between the sole amount of time spent on video games (an average of 2.4 hours per day) and problem behaviors of children and adolescents. On the contrary, Mazurek and Engelhardt [48] write that "the most reliable predictors of problem behaviors were shown to be video game genre and problematic, or addictive, qualities of play". This indicates a strong positive relationship between problematic video game play patterns and both inattentive and oppositional symptoms. Participants who played role-playing or first-person shooter games generally spent

Game genre	**Percent reporting genre as #1 game**	**Percent reporting genre as one of the top 3**	**Most frequent game title by genre**
Action	15.7	30.7	*Star Wars* series
Platform	14.3	25.0	*Super Mario Bros.* series
Shooter	12.9	20.7	*Call of Duty* series
Puzzle/Mini-Game	10.7	16.4	*Angry Birds*
Role-Playing	9.3	20.0	*Pokemon* series
Sports Simulation	8.6	12.9	*Madden NFL* series
Racing	6.4	17.9	*Mario Kart* series
Educational	6.4	8.6	*PBS Kids Online Games*
Simulation	5.7	13.6	*The Sims*
Adventure	3.6	7.1	*Legend of Zelda* series
Strategy	3.6	6.4	*Plants vs. Zombies*
Fighting	2.1	6.4	*Super Smash Bros. Brawl*
Music	0.7	1.4	*Guitar Hero*

Table 2.1: Video game genre preference by children with ASD. [48]

much more time playing games. Furthermore, these video game genres were associated with greater oppositional behaviors.

However, neither of the role-playing or shooter games have shown to yield higher levels of inattention or hyperactivity. The same applies to all the other video game genres. Educational and sports games predicted less oppositional behavior (sports games also predicted less hyperactivity).

Mazurek and Engelhardt [48] state that the results of their study are partly consistent with preliminary findings from the general population. The correlation between problematic video game use and inattentive and oppositional behavior is similar among non-ASD individuals. Further, role-playing games have also been associated with problematic video game patterns in the non-ASD population. In previous studies, they were shown to lead to greater internet addiction in users who played such games, and role-playing games were among the most preferred genres by individuals with a greater risk for internet addiction [48].

Hiltz [49] pursued a study that inspected the differences in play behavior shown by children with ASD when they participate in play with their typically developing peers. The probands of the study, which consisted of eight elementary school students from the ages of eight to 11, were divided into pairs of one participant with ASD and one typically developing participant. Each pair played together multiple times in three different settings: school recess, adult-facilitated play, and kinetic technology using the Xbox Kinect game console by Microsoft. The amount of positive social interaction between the peers was measured in each setting. Hiltz [49, p. 42] describes that "positive social interaction includes social initiations or positive social behaviors that begin with an interaction with a peer and responses to a peer's social initiations". It comprises gestures such as greetings and praise as well as conversational patterns such as asking questions.

Furthermore, [49] provides another explanation of "positive social interaction" by defining several additional variables, which were also controlled in the study; namely affection (showing affection to a peer either verbally or non-verbally), help (offering help or being responsive to help from a peer), compromise (e.g., answering the questions of a peer, triggering a discussion in a positive way), and non-verbal behaviors (laughter, smiling, eye contact). The main objective of the study was to elicit positive social interactions between the participants with ASD and typically developing peers by finding out which play condition (school recess, facilitated play, or kinetic technology play) is the most enjoyable and effective. A stronger emphasis was put on the kinetic technology play condition; it was particularly evaluated if this condition elicited more positive social interactions than the other two analog play conditions. The findings verify this with an average of 21 to 68 percent of positive social interactions on the kinetic condition, while school recess condition had a result of seven to 28 percent and the adult-facilitated condition a result of 11 to 23 percent. Also, playing with the Xbox Kinect game console was rated as a very enjoyable activity by 75 percent of all participants during the study, including both the ASD and non-ASD participants. Further findings suggest that there were no notable differences found between recess play and adult-facilitated play, indicating that both are equally effective for eliciting positive social interactions between participants with ASD and typically developing adolescents [49].

Mazurek and Wenstrup [50] initiated a study that looked into the nature of television, video game, and social media use in children with ASD compared to their typically developing peers. There were 200 participants in the ASD group and 179 participants in the non-ASD group. Akin to the study in [48], the methodology applied in [50] included the collection of data through parental reports. Parents completed measures on their children's screen-based activities by filling out a form, allowing the authors of the study to obtain various child and family variables (e.g., age, race, parent marital status, household income, time spent on screen-based media, patterns of video game use). The study concluded with the result that children with ASD spent roughly 62 percent more time with video games and television than all other non-screen activities combined. It was reported that they, on average, invested 4.5 hours per day into screen-based activities and 2.8 hours per day into non-screen activities (which were comprised of, e.g., homework, studying, and spending time with friends). Another finding that emerged from the study is that children with ASD played video games more frequently (2.0 hours per weekday and 3.1 hours per weekend day) than their typically developing peers, who rather spent, on average, approximately 87 percent more time on non-screen activities (5.7 hours per day) than on screen-based activities (3.1 hours per day).

In addition, the study found that the majority of children with ASD rarely play online multiplayer games compared to their typically developing peers. In fact, the majority of children with ASD (76% of boys and 90.3% of girls) never played these types of video games. Furthermore, the research showed that boys with ASD are also more likely to never play video games with others (in person or online) compared to neurotypical boys. The same aspect was also true for the girls with ASD who participated in the study.

The authors state that children with ASD indeed have a strong preference for video games, but the associated underlying reasons are not clearly understood. It is assumed that, due to studies consistently showing that many individuals with ASD have strengths in visual perceptual skills [51, 52], visual media may be more appealing to them [50].

Anderson-Hanley et al. [53] performed two pilot studies that looked at the effect of exergaming (a portmanteau of “exercise” and “gaming”) on cognitive functioning and repetitive behavior in children with ASD. According to the authors, a lack of physical activity in children and adolescents with ASD has been shown in previous studies to negatively affect autism-typical symptoms (mainly repetitive behavior). Through exergaming, physical movements are intertwined with the controls of a video game, providing both a physical and mental exercise.

The first pilot study examined the positive effects of exergames on behavioral and cognitive skills in 12 children and adolescents between the ages of 10 and 18 with an ASD diagnosis. They performed an acute bout of Dance Dance Revolution, a well-known rhythm-based dance game, for 20 minutes and a control task (a placebo condition) on other days. In the second pilot study, a different form of exergame intervention was chosen: Cybercycling, in which a traditional stationary bicycle was linked with a video game (Dragon Chase). 10 additional children with ASD completed a 20-minute bout of cybercycling. In both intervention groups, repetitive behaviors and executive functions were assessed before and after each activity.

In summary, Anderson-Hanley et al. [53] concluded that repetitive behaviors decreased significantly and executive behaviors improved for participants in both pilot studies compared with the control task. Both exergames thus had a similar positive outcome.

2.2 Serious Game Interventions

Whyte et al. [36] directed a literature review on computer-based gaming interventions for individuals with ASD, with a strong emphasis on serious games and their design principles. They specifically focus on the generalization of learning and transfer of skills, trying to find evidence whether the computer-based training programs that have been developed so far lead to a generalization of newly acquired skills to a real-world context. In [36], the term "generalization of skills" was restricted to refer mainly to training effects that solely appear within training procedures without generalization (*training effects*), effects that lead to a generalization of skills to other similar computer-based tasks or standardized tests (*near-transfer*) and *far-transfer* of skills in real-world contexts (e.g., social interactions with others). Furthermore, the key elements of serious game design should be associated with both near- and far-transfer of skills. These elements include having a storyline, short-, medium-, or long-term goals, types of rewards and feedback about goal progress (e.g., rewards for correct responses or cumulative point systems), different levels of difficulty, and individualized, tailored training for the patient playing the game (e.g., having a clinician or teacher present).

Whyte et al. [36] stress that these serious game elements are being rather rarely used in existing computer-based interventions in the context of autism research, and there are even fewer studies that address the near- and far-transfer aspect of learning. [36] suggest that this may be related to limited learning during the interventions in these studies. Also, in existing studies investigating computer-based interventions for individuals with ASD, evidence of learning was observed in the participants. Some of them showed evidence of near-transfer to other similar computer-based tasks, but only a few studies reported a generalization of acquired skills to real-world situations (far-transfer). This aspect is likely related to the core characteristic of individuals with autism that they have difficulties with generalization of learning and skill transfer to non-training contexts. The authors conclude the literature review by outlining that it is important for future research to focus on core issues related to the design of the computer-based interventions (or serious games) [36].

Zakari et al. [54] conducted a systematic literature review on studies in 40 serious games designed for children with ASD released from 2004 to 2014. The games were listed in terms of the platform they run on (either desktop, mobile, or tablet), if each game utilizes either 2D or 3D graphics, has learning purposes, gaming aspects, and user interaction methods. [54] outlines that serious games targeting children with ASD have been developed mainly for desktop computers and laptops (70 percent). However, games on smartphones and tablets for educational purposes are growing in popularity due to the small screen size being helpful for the children's attention. The touch screen also allows for easier and more intuitive means of interaction.

The main two purposes of serious games for children with ASD are education and therapy. 54 percent of the research addresses serious games development geared towards improving social skills and interaction, indicating a larger interest in this area than others. In one example study, Zakari et al. [54] found out that children with ASD like to play with a game character that shares similar traits to their real-life identity, such as gender. On the contrary, there was repetitive behavior measured in these children when some of them purposely selected wrong answers because they liked the feedback sound.

26 percent of the research is about serious games for the purpose of learning new vocabulary and speech therapy purposes. Studies on games aiming to help children with ASD with sensory processing disorder (SPD) are on the much lower end, with one study that only focuses on vision.

After evaluating the 40 serious games, according to [54], the following gaming aspects or mechanics are commonly incorporated into serious games for ASD children:

- Matching of shapes (e.g., with other objects)
- Filling of shapes
- Game level-up
- Multiplayer

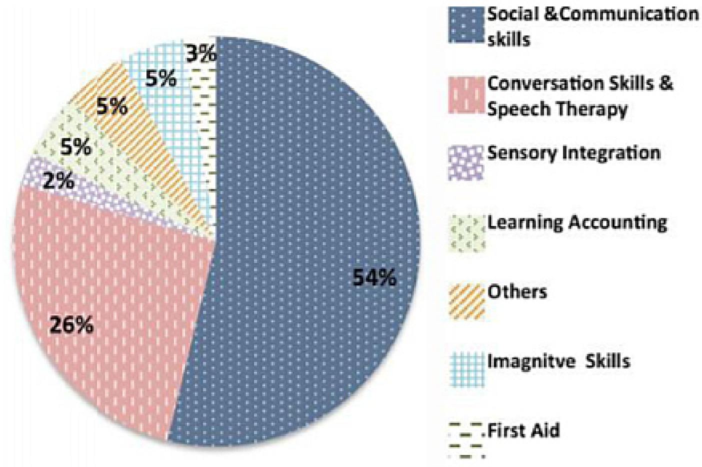


Figure 2.1: The different purposes of serious games for children with ASD. Adapted from [54].

- "Collecting or beating objects, constructed shapes, and puzzle pictures" [54, p. 102]

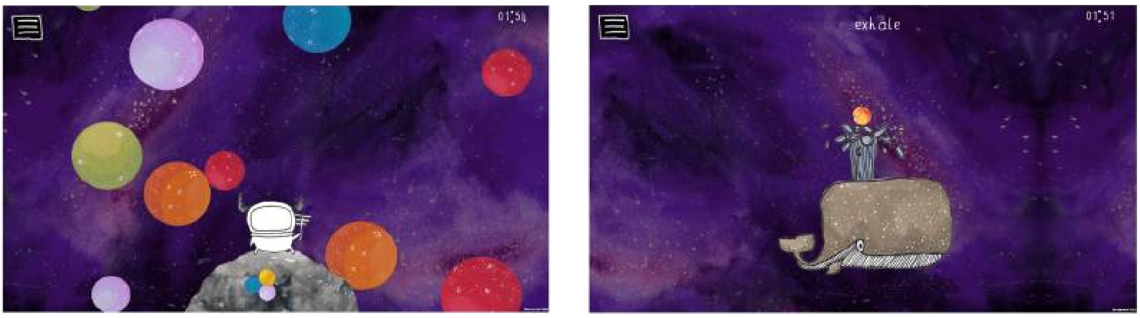
The authors came to a close by pointing out aspects that they consider necessary for designing serious games targeting children with ASD. Firstly, games should "provide a customization mechanism [...] to allow parents and teachers to discourage certain player behaviors, such as repetitive behaviors" [54, p. 103]. Also, they should provide further mechanisms to analyze the progress and build-up of the ASD child's skills, such as data evaluation or visualization tools [54].

Carlier et al. [1] carried out a recent proof-of-concept study that looks at the design and implementation of serious games in the area of anxiety and stress reduction in children with ASD. The games were created to empower the children and their parents, who often suffer from increased levels of stress due to them having to face challenges when caring for their children (e.g., because of the challenging behavior of the child). A mobile game named *New Horizon* as well as the *SpaceControl* application were developed as an intervention means for the ASD children and for parents as an empowerment tool, respectively. The Unity game engine was used for development, given its functionality to build and deploy applications on multiple platforms, such as Android and iOS.

New Horizon is a 2D exploration and puzzle game that incorporates an infinite universe with an infinite amount of planets that can be explored. The main goal of the game is to play mini-games and thus gain experience as a player. Two of these mini-games are a memory and a platformer game, respectively, although they do not utilize cognitive behavior therapy (CBT) relaxation techniques for anxiety relief. The objective of the memory mini-game is to remember and replicate a sequence of objects which appear in a specific order on the screen. The aim of the platformer game is to reach the end of a level, bypassing obstacles that approach the player character.

In addition to that, two mini-games were developed that do make use of relaxation techniques. In fact, these cover guided imagery (GI) and focused breathing, which have been, according to [1], proven to be effective in relieving stress and anxiety symptoms. GI is defined as a technique that "utilizes the subject's personalized images to promote health through several standardized, yet adaptable, techniques, including relaxation/stress reduction" [55, p. 7]. Focused breathing in the form of breathing exercises or meditation has various benefits on mental and physical health. For instance, the parasympathetic nervous system can be activated, possibly calming the nerves and slowing down the heart rate [56].

Figure 2.2 shows the games that employ the aforementioned relaxation techniques. The goal of the senses mini-game is to collect stardust inside the bubbles by popping those of the correct color, whereas, in the breathing mini-game, one has to concentrate on their breathing, inhaling, and exhaling at the right time to earn rewards.



(a) Senses mini-game. (b) Breathing mini-game.

Figure 2.2: Images of *New Horizon* showing the senses mini-game and the breathing mini-game, respectively.

SpaceControl, on the other hand, is an application to "empower the parents and to reduce the burden of dealing with daily temper tantrums" [1]. In the tool, information about the gaming behavior of the children is represented visually, providing parents a means for observing and understanding their children's feelings. Moreover, one is able to obtain information about the mood of the children. This is indicated either by the child maintaining the same mood after playing a particular type of mini-game or whether or not they find a specific type of mini-game enjoyable. Signs of obsessive behavior, as well as the favored types of mini-games by the child, can also be implied by the number of times a mini-game has been played [1].

Carlier et al. [1] took an interdisciplinary approach for this proof-of-concept study. The study was established in cooperation with researchers from the Ghent University Faculty of Psychology and Educational Sciences. The design and implementation process of the mini-games was further supported by an occupational therapist, a behavioral therapist, and a psychologist. The cooperation of the researchers of [1] with the therapists resulted in the creation of guidelines that should be considered when developing a serious game for children with ASD. It is emphasized by the therapists that these guidelines do not set fixed standards. They consist of the following six aspects:

1. **Sound and Music:** Turning off music and sound effects should be possible separately and at any time. There should be no interference of the turned-off music or sound with the gameplay. For instance, as mentioned exemplarily by [1], "if negative action is accompanied by a sound effect, it should still be clear that it is a negative action when the sound is turned off, by, for example, adding a vibrating effect".
2. **Background Story:** The presence of a background story should not interfere much with the overall gameplay. When it is too present, the game may be too demanding for the child, causing a possible loss of concentration and making the child more attentive towards the story rather than the game per se.
3. **Language and Text:** The game should be devoid of any language and text that make use of figures of speech and as straightforward as possible. An example given by [1] is that the phrase "Watch out, you can't swim!" may be confusing in the sense that the playing child might feel that "you" refers to him or herself and not to the player character, possibly leading to a confused reaction of the child (e.g., "But I can swim!").
4. **Actions and Goals:** This aspect suggests that the goals of each game should be specific and concrete, and the actions needed to reach those goals should be made explicit to the user. For instance, if one gives a correct answer in a game, this should

be reinforced by the use of special effects and audio, making it more apparent to the player.

5. **Simplicity:** When designing a serious game for stress and anxiety relief, one should keep it visually simple. There should be only a limited number of colors in the game as well as limited game settings, which only concern functional game objects and sounds. Children with ASD might be overwhelmed by too many sensory stimuli, leading to possible distraction or increased stress and anxiety.

6. **Scoring:** It is suggested that there should be no negative scores, and all negative text should be reduced to a minimum. In case the player is not able to complete, e.g., a level in a game, he or she should still feel motivated to keep playing the game [1].

After the recruitment phase, in which the participating families were selected and informed about the study process, usability tests took place for a duration of two weeks where the child participants with ASD and their parents could test the *New Horizon* game as well as the *SpaceControl* application for the parents at home. During the usability tests, one of the parents was interviewed and had to complete a questionnaire regarding the anxiety symptoms of the children. In total, three children with ASD and signs of stress and/or anxiety between six and 10 years of age completed all study phases (including the post-interviews after the test phase). Two participants dropped out during the test phase.

The results of the usability tests showed that the children overall enjoyed playing the *New Horizon* game, even though they were distracted by the fact that they were possessing an own smartphone. The breathing game was the least popular mini-game among the children because it was perceived as boring, while the memory game was assessed as the most enjoyable and hence most popular mini-game. Both applications were tested for two weeks.

The study results and the game's test phase concluded that the participants had indicated decreased levels of anxiety and stress. In the post-interviews conducted after the game tests, however, it turned out that the game was not played when the children were feeling anxious or stressed. According to the authors of [1], this may be linked to the hesitance of the parents to let their children play the game when they are throwing temper tantrums. Furthermore, despite the interdisciplinary layout of the study and collaborating with psychologists and therapists, the authors state that this does not by all means lead to a "fully immersive and engaging system" [1].

They conclude the study by asserting that, in order to create an enjoyable and relaxation-promoting game for children with ASD, it might also be mandatory to incorporate children with ASD themselves into the design process [1].

Wojciechowski and Al-Musawi [57] presented an iPad serious game called *Let's Play* with the objective to support children with ASD in the process of learning new words, their meanings, and pronunciation. Parents could select a limited set of objects (or words) for their children to learn. In the game, the children were shown a cartoon image or a photo, which they could touch, causing the name of the object to display and be spoken aloud. This lead to the two participants of the study pursued in [57], children of ages three and four, being able to enrich their vocabulary and improve pronunciation, eventually leading to improvements in social communication. To render the teaching process as efficient as possible, the parents' voices were recorded during the pronunciation of the words. As stated in [57], this ensured that autistic children would not hear new and unknown voices, making the children feel safer overall. Familiar voices or sounds would let them feel more comfortable.

The study lasted for over 12 weeks. The authors made use of a smartwatch and a smartphone in the first- and second-week sessions to access the game, respectively. They observed that the probands could learn new vocabulary faster utilizing these intervention approaches than by unsupported learning situations that solely consisted of listening to words repeated by the parents. As a result of the intervention using *Let's Play* and learning new words, it was reported that both children had indeed increased communication with others. Also, both parent pairs were satisfied with the benefits of the interventions. They expressed willingness to continue letting their children play the game, assisting them by pronouncing new words multiple times each day [57].

Caria et al. [58] presented a set of three web-based serious games that pursue the goal of aiding children with ASD in their understanding of the concept of money and how to use money in their daily activities. A user study was carried out with six participants from ages 16 to 22, all diagnosed with high-functioning ASD, to assess the effectiveness of the games.

The serious game is comprised of the three games *Money*, *Money Change*, and *Buy It!*. The game *Money* was developed with the primal objective to impart knowledge to children with ASD on various currency denominations and is itself made up of three mini-games, namely *Image and Image*, *Image and Text*, and *Sum.* Figure 2.3 shows a screenshot of the *Image and Text* mini-game, which aim is to facilitate learning about the names of coins and banknotes. The player's task is to drag a certain coin or banknote onto its corresponding name. Overall, there are eight levels that increase in complexity. On the contrary, the *Image and Image* mini-game's purpose is to learn money denominations by association (i.e., dragging coins or banknotes onto corresponding similar looking coins or banknotes), whereas the *Sum* mini-game was designed to teach the player that it is possible to get further money values as a result of combining coins and banknotes.

The *Money Change* game allows the player to learn about the concept of money change, while *Buy It!* was created to train players in money management by simulating real-life situations (e.g., it includes tasks where the player is asked how a certain item can be purchased with a specific amount of money).

During the evaluation phase, the six participants with high-functioning autism were organized into groups of three individuals each. The first group was composed of young adults (between ages 20 and 22), and the adolescents were part of the second group (between ages 16 and 17). The majority of the adults in the first group were relatively tech-savvy; all of them used a smartphone, and two of them both tablets and PCs. Only one individual did not use tablets and also used the PC very infrequently. All the devices were used mainly for browsing the web and playing games.

The adolescent participants in the second group exhibited a varying affinity for technology. One individual was particularly fond of technology, even possessing knowledge of the programming language JavaScript. Another user seldom used his smartphone and had no experience with PCs. The third participant had little experience with tablets and smartphones, which were used only for photos and browsing the web. But instead, he was very familiar with PCs.

According to the authors, the result of the study was encouraging, which reinforces the potential of the game to be used as a tool for training children and adolescents with ASD on practical life skills. In fact, the game was perceived positively by all participants for the most part, especially by the adolescent group members. The *Image and Image* and *Image and Text* mini-games were assessed as too easy, and the *Sum* mini-game as slightly too

Figure 2.3: A screenshot that shows an exercise of the *Image and Text* mini-game. Adapted from [58].

difficult by both groups. In total, two trials were conducted: in the first trial, the majority of the participants exhibited difficulties with calculations, some of them even having to use calculators, and occasionally there were problems in correctly reading the texts included in the *Image and Text* mini-game. However, during the second trial, some users showed increased progress in solving the tasks, with the number of errors done by a user being less than in the first trial.

Caria et al. [58] conclude the study by pointing out that there is a plan to evaluate how far the acquired skills through the serious game can be applied to real-life contexts (i.e., a far-transfer of skills, as discussed in [36]). They are aware that individuals with ASD, who go through learning-based intervention programs, usually tend not to generalize well to novel real-life contexts and environments. Hence, further research in that area needs to be done (including larger samples and control groups) to be able to evaluate the potential long-term effects of such gaming-based interventions [58].

2.3 Virtual Reality Interventions

The focus on research describing interventions using virtual reality (VR) technology for children and adolescents with ASD has increased over the years [59]. VR can be an effective tool to promote and enhance an ASD children's development in terms of social and communication skills [40]. Similar to serious games, approaches and interventions using VR in the field of autism have been reported to be helpful for learning [60, 61], education and teaching purposes [62]. One compelling difference between VR and serious games, though, is VR's ability to provide users highly realistic immersive environments that simulate real-life complexity. These realistic environments can be comprehended by children and adolescents with ASD, enabling them to make decisions based on the similarity between the real and virtual world [40].

Ke and Im [63] conducted a multiple-baseline study that investigated the implementation and effect of virtual reality interventions (e.g., simulation of social interactions) on the interaction and communication performance of children with high-functioning autism (HFA). The probands of the study were four children of nine or 10 years of age with a medical diagnosis of Asperger syndrome or HFA. The VR intervention program was made of three real-world scenarios: (1) the recognition of body gestures and facial expressions of another partner in the VR world, (2) interacting socially at a school cafeteria through responding to conversational initiations by other peers and maintaining these interactions with them, and (3) initiating and maintaining conversations at a birthday party.

Figure 2.4: A screenshot of the VR scenario showing a birthday party.
Adapted from [63].

Each study participant was video-recorded, and their virtual and physical communication behavior was observed during gameplay. During the intervention, the participants proved to have increased performance in responding and interaction maintaining, particularly in the cafeteria scenario. The majority of participants also showed an improved performance in interaction initiation, greeting, as well as conversation-ending. After the intervention, they were found to have improved social competence measures, such as better body gesture recognition skills.

As suggested by [63], a much larger sample size would have helped build a better empirical evidence base. However, according to the authors, gathering more participants for the study was almost impossible due to the study targeting children with ASD, a special learner group [63].

A recent pilot study pursued by Johnston et al. [40] presents an interactive VR game designed for auditory hypersensitivity therapy in children with ASD. Six ASD participants displaying hypersensitivity to auditory stimuli were recruited, of whom four were male and two female, between the ages 16 and 19. All of them had a formal medical diagnosis of ASD.

The main objective of *SoundFields* was to serve as an intervention tool for anxiety reduction in those subjects regarding identified problematic sounds. As a means of aid, head-tracked binaural-based spatial audio was used that helped render three-dimensional audio stimuli that simulated realistic acoustic environments of feared sounds. To the authors, it was important as a serious game to feature story-driven gameplay with long-term goals, as described in [36]. In the game, one is presented with a non-playable character (NPC) named Fabian acting as a guide in the game. The player's main task is to help him to track down and collect virtual characters that are spread all over the environment (see Figure 2.5), where some emit sounds that may be received as disturbing.

The participants of the study played the game weekly for 30 minutes for over four weeks, with the result being that intervention succeeded in significantly reducing the anxiety of the subjects towards target audio stimuli.

One weakness of the study is, as with many other studies in the field of technology-based interventions for individuals with ASD, the limited sample size of six persons. The authors state that future research should try to replicate their findings with larger intervention groups using the techniques in the study (i.e., a virtual reality game utilizing binaural-based spatial audio) [40].

Mesa-Gresa et al. [64] performed a systematic review on the general effectiveness of virtual reality in children and adolescents with ASD. After a thorough literature selection process and subsequent analysis of 31 articles, the authors concluded that there is only moderate evidence for the efficacy of VR-based interventions in ASD. Like much of the

Figure 2.5: A screenshot showing the virtual environment of SoundFields.
Adapted from [40].

technology-based intervention studies in the ASD field, the majority of studies addressed improving the daily lives, social communication, and interaction skills of individuals with ASD by providing virtual environments that represent social situations. Other studies had looked at improving emotional skills, treating anxiety and phobias, and increasing motivation for physical activities [64]. In a similar meta-analysis by Kalami et al. [65] who reviewed 33 studies, skills training using VR technology demonstrated only moderate effectiveness. However, the authors highlighted that studies addressing training in daily living skills yielded better results than studies that aimed at improving social reciprocity skills, emotional skills, and cognitive skills. Furthermore, in studies conducted with high-functioning ASD patients, higher training effectiveness was observed, although it decreased substantially when the patient suffered from an accompanying comorbidity alongside ASD [65].

Research examining the implementation of VR as a tool for teaching purposes has been done by Josman et al. [62]. They built a VR environment that should facilitate conveying knowledge in street crossing, which is a critical area for many children with ASD because it means dealing with potentially dangerous situations and is an important step in their pathway to independence. The major objective of the study was to assess the potential of the desktop VR tool for skill generalization; it was observed whether the acquired skills in the virtual environment actually transferred to real life. The participants of the study were assigned to a research group and a control group, which consisted of six children with ASD and six grade and gender-matched children with typical development, respectively. The children's performance while street crossing in the virtual environment was assessed.

Each participant was video-recorded during the intervention, and outcome variables regarding street crossing were measured, such as the number of times a child looked to the right and the left, if the street was crossed under a red or a green traffic light, and how often accidents were made. Josman et al. [62] eventually found out that all the participants with ASD had improved street-crossing skills due to the training in the VR environment. Also, compared to the baseline, half of the participants with ASD demonstrated significant improvement in protected real street-crossing scenarios [62].

2.4 Other Technology-Based Interventions

Bharatharaj et al. [66] designed a parrot-inspired robot to improve the learning and social interaction of young adolescents with ASD. The robot named "KiliRo" had cameras, a speaker, a microphone, and further built-in modules needed for establishing communication between the robot and the ASD children (such as a text-to-speech module and a speech synthesis module). In [66], a pilot study was carried out with 10 child participants having a confirmed ASD diagnosis between seven and 11 years of age recruited from a special school in Chennai, India. The study was undertaken over a three-day period with nine sessions. Each session lasted for at least 15 minutes and was separated by 15-minute breaks.

Three conditions were defined in the study: one at baseline without human and robot interaction, another one with human interaction (a new person was introduced to the participating children), and the final one with robot interaction. During the baseline condition, all 10 participants and their behaviors were monitored; for instance, when the participants looked at the person or the robot, when they touched the person or the robot, or when they had verbal or non-verbal communication (e.g., by means of body gestures) with the person or the robot.

The results of the study showed the participants had significantly increased interaction capabilities during sessions with the robot in contrast to sessions with another person. Limitations of the study include the small sample size of participants, therefore limiting generalization, and the study not being long-term [66].

Rudovic et al. [67] went a step further and presented a personalized machine learning framework using deep learning for robots used in therapeutic settings to help children with ASD. The purpose of the researchers is to create a robot that can automatically and naturally perceive human affect (mimic, gestural, or vocal behavior) and engagement of children interacting with the robot. Therefore, it should be able to establish and maintain interactions with children.

The robot NAO by the company SoftBank robotics was used in this study, and the developed framework was evaluated on 35 children with ASD, 17 from Japan, 18 from Serbia, from the ages three to 13. During the study, Rudovic et al. [67] gathered multimodal data (audio, video, and autonomic physiology) of the children through recordings of facial expressions, gestures, and body movements as well as measurements of heart rate, body temperature, and skin conductance. The deep learning networks of the robot, which architecture was in fact made of feed-forward multilayer neural networks, were constructed from layers of all the collected data. In addition to the multimodal data, the networks were trained on information about the ASD diagnosis, the cultural background, and gender of the child and tested on unseen data not used for training the model.

The study incorporated 35-minute sessions where the participants showed different reactions to the robot, from looking bored and unimpressed to being very excited and animated, laughing, and touching the robot. The researchers note, though, that the robot and the developed machine learning framework, respectively, overall did a good job in estimating the child's behavior for the majority of the children that participated in the study [67].

Apart from robotics, computer-assisted instructions (CAI) have also shown to be effective in the field of autism therapy [68, 69, 70]. CAI per se is a broad term that encompasses the use of software tools (that includes graphics and illustrations) to convey skills and can make learning more comfortable for children with ASD due to their most significant stressor being social interaction with other humans [70]. For instance, Bauminger-Zviely et al. [68] conducted a study in which the effectiveness of two computer programs for teaching collaboration and social interaction was assessed on 22 children with ASD. The following two computer programs were developed: *Join-In* and *No-Problem*, with the former being a program for learning collaboration and the latter for training social conversation. The methodology used in the study included means of measurement such as problem-solving, Theory of Mind, and a dyadic drawing task. Bauminger-Zviely et al. [68] found out that the programs aided in improving the participants' socio-cognitive skills, especially in finding active solutions to social problems and building a more thorough understanding of collaboration and social conversation [68].

2.5 Summary and Implications

The primary objective of this literature review was to explore the effects and outcomes of computer-based interventions in individuals with ASD, mainly by means of playing video and computer games. The results of this review indicate that, despite a variety of studies having comparatively small sample sizes, these kinds of interventions may have quite a positive effect on this target group in terms of improving cognitive, social interaction, and communication skills. In addition, there seems to be the general consensus that playing video games is a much-preferred activity by children and adolescents with ASD (e.g., [48, 41, 45, 50]).

Although some studies reported that children with ASD generally tend to spend lesser time playing video games with others because of their traits [44, 48], others show that joint video game play with friends, including online games and kinect technology, can improve friendship quality [45, 49] and companionship with their best friend [47].

Overall, video games, including serious games and virtual-reality-based games, have the potential to positively affect the deficits of this target group, which include lacking social and communication skills and repetitive behavior. A pilot study with exergaming was successful in significantly reducing repetitive behavior in participants within the trial group [53]. Serious games may ensure that children acquire new skills (e.g., [36, 54, 57]) and also may be beneficial as a tool for therapy [1].

Also, technology-based interventions such as virtual reality, robotics, and computer-assisted instructions (CAI) may provide a predictable, engaging, and safe environment for children with ASD. In particular, these potentially allow for opportunities to adapt to potentially stressful stimuli that occur during social interaction.

The study conducted in [48] reported that the most preferred video game genres of the participants were action games (e.g., the *Star Wars* series), platformer games (e.g., the *Super Mario Bros.* series), and shooter games (e.g., the *Call of Duty* series). However, the action and shooter genres were also associated with problematic video game play patterns, such as showing higher rates of oppositional and addictive behavior.

Therefore, one should not completely disregard the potential negative aspects of video game and technology use. Mazurek [71] states the following in this regard:

> "*Due to the nature of their disorder, children with ASD appear to be at risk for becoming preoccupied with video-game technology and for engaging in these games to the exclusion of other activities, which may lead to negative behavioral and health outcomes. Leveraging children's fascination with technology should be balanced with preventing and reducing such undesirable effects.*" [71]

Consequently, when developing a computer game targeting children and adolescents with ASD, it is crucial to consider both positive and negative effects a game can potentially yield in real-life.

Chapter 3

Design Guidelines for Computer Games Targeted at Children with ASD

In literature, there exists a number of design guidelines for games targeted at individuals with ASD, mainly in the area of serious games, focusing on eliciting learning effects (e.g., [1], [72], [73], [74]). However, as the project developed as part of this thesis is not a serious game, a custom set of design guidelines was created, partly influenced by the various findings from literature (mainly by the guidelines in [72]). The guidelines were created after evaluating the literature discussed in Chapter 2, obtaining a clear idea of how children and adolescents with ASD behave during gameplay and what circumstances determine the effects video games have on the behavior of this target group.

The guidelines are divided into *general guidelines* and *game-specific guidelines*. General guidelines concern the general design of a game in terms of user interface, interaction, and usability (i.e., non-functional requirements or quality attributes). The main focus of the game-specific guidelines is on the game design itself. This chapter will discuss all of the guidelines in detail.

3.1 General Guidelines

3.1.1 Low to Moderate Stimuli

When designing games, care should be taken not to overdo visual stimuli and colors, as many children with ASD are prone to sensory overload and may become anxious or distracted during play. All graphics should be solely functional to the goal (i.e., serving only the current task in the game). Similarly, sound elements should be functional to the game task but also used appropriately as audio feedback. For instance, fanfare sounds could be explicitly played when the player reaches a specific goal or receives a reward. Overall, both graphics and sound should be simple and not cluttered, as too many stimuli can quickly have a stress-producing effect on children with ASD.

3.1.2 Dynamic Stimuli

The motivation and engagement of a child with ASD can be improved if their good performance in play is rewarded. What can work well as a positive motivational reinforcer is presenting appropriate animations or playing music that generates pleasure. According to the author's experience in [72], children with medium to low functioning autism do not particularly value quantitative performance outcomes (e.g., points or gained extra time) as rewards, so game designers should consider incorporating dynamic stimuli in any case. Furthermore, they also help to maintain the child's attention. A prolonged static image, on the contrary, can cause undesirable behavior, such as motor rigidity (e.g., staring at the static image for an extended period of time).

3.1.3 Minimum Transition Times

Transition times between different game states (e.g., when loading a level) should be kept as short as possible. If they are too lengthy, the player's attention or concentration may be compromised. Generally, it should not take too much time to start game sessions, as they are restarted over and over again.

3.2 Game-Specific Guidelines

3.2.1 High Customizability

The game should be accessible to a variety of children with ASD. This means that there should be mechanisms in the game to adjust its demand and difficulty to the particular abilities and needs of the child with ASD, as these are unique to each one. What may feel satisfying and rewarding for one child may be more stressful for another child.

3.2.2 Clear Goal

At the beginning of the game, a single explicit goal should be set that can be reached within one game session. This means that there should be only one main task to focus on in the game, which fits the fact that many children and adolescents with ASD have repetitive behavior, wanting to engage in the same activity. Additionally, the instructions used to illustrate this goal should be accessible and easily understood by players and not contain language or text that could be misinterpreted.

3.2.3 Avoiding Negative Scores and Text

There should be no negative scores for performances in the game. Furthermore, the use of negative text should be avoided (e.g., "You lost!"). In order to avoid moments during gameplay where the child gives up or becomes frustrated, negative feedback should generally be kept to a minimum or used in a targeted manner so that the child remains motivated to continue playing the game.

3.2.4 Focus on Repeatability and Predictability

Repeatability is an essential aspect of designing games for children with ASD. It can facilitate practice and mastery of a skill and provide control over the rate of learning. Repetition of a task can also lead to improved predictability, which is oftentimes necessary for children with ASD to better understand the (play) world around them. Additionally, unpredictable situations can cause increased anxiety for children with ASD and make them feel uncomfortable. A well-designed game can provide a safe environment where children can practice and master new skills.

3.2.5 Progression During Game Play

The player must be able to make progress in the game, which can also be saved and resumed later. Accordingly, the game should increase in difficulty proportionally as the player advances, demanding more of their motor and cognitive skills. In RPGs, the player character's growth should be directly related to the progress in the game, meaning that one should not have to spend real-world money to progress, for example, as is the case in many free-to-play mobile games. Furthermore, the evaluation of success in the game should be free of emotion (i.e., there should be no other character telling the player how good they have performed). The player should be instead given a rewarding experience in any case by making success immediately visible (i.e., immediate feedback).

3.2.6 Less Story Elements

Story events should not interfere as much with the gameplay, or the attention of the child may shift too much towards the story, potentially leading to a loss of concentration. For instance, when developing a role-playing game, the number of NPCs giving instructions to the player should be kept to a minimum. If an NPC in a role-playing game warns the protagonist that it is too dangerous to go on a certain path, which must be walked to move forward, the child may not continue and even entirely stop playing the game for that reason.

3.2.7 Character Customization

The game should provide a way for the child to create a visual representation of themselves (i.e., an "avatar"), whether through creating their own player profile or naming the game's protagonist after themselves. Optimally, it should be possible to customize an avatar in such detail that it represents the player themselves (for instance, in terms of skin tone and hair color). When the playing child sees their own representation in the game, they feel connected to it, and a link is formed between their own movements and the reaction in the system.

3.2.8 Elements of Surprise

Although predictability is an important factor in developing games for children with ASD (see subsection 3.2.4), there should always be something new or surprising in the game.

This aspect is important in that it motivates the child to stay interested in the game, play it repeatedly, and get better at it without it quickly becoming uninteresting to them. It is therefore important to preserve a balance between predictability and surprise.

Chapter 4

Brain Hero Wanderer: A Roguelike Game

The guidelines discussed in the previous chapter were applied to design and develop the game *Brain Hero Wanderer* as a proof of concept. This chapter will thoroughly elaborate on the game design and implementation details, and provide an analysis of the game according to the developed design guidelines.

4.1 Game Design

Brain Hero Wanderer is a 2D roguelike game in which the player takes on the role of the fictional extraterrestrial character named "Brain Hero". The term "roguelike" describes a subset of RPGs that were implicitly or explicitly inspired by the game *Rogue*, which was initially released in 1980 and had an entirely ASCII-based interface, being typical for that time. These games share core features such as a randomly or procedurally generated game environment, the permanent death of the player character (or *permadeath*), grid-based movement, and turn-based gameplay. The randomization aspect has the purpose of enhancing the replay value of the game, since not only is the game environment randomly generated when the game starts, but items and monsters are also randomly placed. The permadeath feature involves the fact that once the player character is defeated, the game (i.e., the current "run") has to be started over from the first level. Saving games is generally possible; however, the stored save file is deleted upon character death or resumption. Moreover, permadeath should, according to the Berlin Interpretation [75], be enjoyable rather than punishing, meaning that this aspect can also contribute to the replay value of the game.

Consequently, *Brain Hero Wanderer* is a game inspired by Rogue, but employs two-dimensional graphics instead of ASCII symbols. In the game, the player traverses 17 randomly generated areas in which they have to fight monsters to proceed forward. There is a strong focus on resource management and exploration, as the player has to think of strategies through using items (and also equipment) in the best way possible to reach later levels. Furthermore, the player can move in eight directions (up, down, forward, backward, and diagonally in each of the four directions) in the game. Due to the turn-based nature of the game, whenever the player character performs an action, such as moving, attacking, or using items, all monsters in the surrounding area perform one action as well. There are also hidden traps placed randomly on the map, which have varied effects on the player character.

Figure 4.1: A screenshot of *Rogue*.
Adapted from [76].

Storyline-wise, there is only a low amount of storytelling compared to traditional RPGs, due to a particular emphasis on actual gameplay. However, the game employs a pre-written story that adds context to the player character and the tasks that have to be fulfilled. The game follows a character named Brain Hero, who is on his way home to his home planet, but the UFO suddenly runs out of energy. As a result, the hero has to make an emergency landing on an unknown planet. The goal of the game is to obtain the *Gem of Gaia*, which was torn apart into seven pieces. Those seven gem pieces have to be collected that enable the hero, when all gathered together, to restore the Gem of Gaia, in turn bringing back the energy of his UFO. The Brain Hero travels through dungeons located on the unknown planet and tries to find the gem pieces by traversing through the dungeons and finding the exits.

The design decision as to why there are only a few story elements comes mainly from the guidelines discussed in Chapter 3, stating that a background story can lead to undesirable distraction in children with ASD. Another rationale for the decision is that, as asserted by John Harris [77, p. 84], "[...] human minds search for patterns in series of random events, recognizing them as narratives, and in attempting to explain them subconsciously attribute thought processes to the actors. This is the root of superstition, some would say of religion too, and it's why roguelikes don't lack for stories. What they lack are pre-written stories."

During the game design process, consideration was also given to maintaining the "Flow", a concept developed by psychologist Mihály Csíkszentmihályi, describing a mental state characterized by a deep and energized focus in an activity, which leads to enjoyment and fulfillment. The central elements of Flow include taking on challenging activities that require skill, the merging of action and alertness (i.e., a person is completely absorbed in an activity so that the activity becomes almost automatic), and an altered sense of duration of time [78]. This state is experienced by gamers when they are so engrossed in a video game that they lose track of time and forget external pressures. In order to maintain the Flow experience, the balance between the activity's challenges and the abilities of the player must be ensured. If the activity is too challenging, it becomes overwhelming and causes anxiety. If the activity provides too little challenge, it evokes boredom [79]. Since the player character in *Brain Hero Wanderer* can level up and becomes stronger while they progress, they enter larger dungeons and encounter more powerful monsters with varied abilities. At the same time, the game tries to maintain the balance of increasing difficulty between too challenging and not challenging enough.

There are 24 different types of monsters in *Brain Hero Wanderer*, with almost each one having one or more unique abilities. During the game design process, attention was paid to the fact that the monsters are more like animals or other fantasy creatures and do not look humanoid. Furthermore, there are 44 objects (items and equipment) in total that can be collected. Equipment in the game do not correspond to weapons known from classic roguelikes and RPGs, as they do not fit into the narrative of the game. Instead, they resemble objects like rings and stones, with rings increasing the protagonist's offensive abilities and stones increasing the protagonist's defensive abilities. There are also additional equipment items with unique effects that, for instance, protect the player character from negative status effects or increase their hit accuracy. The player character can be equipped with three pieces of equipment simultaneously.

Other objects that can be collected in the game are cookies. They are also randomly generated with a random amount and increase the player's score upon collection. Cookies also have a greater factor in calculating the player's score.

Figure 4.2: A screenshot of *Brain Hero Wanderer* showing the player character being cornered by monsters.

4.2 Game Details

This section will focus on the game itself, including an elaboration on the mechanics of the game, i.e., what kinds of interactions there are between the player and the game.

For the game, a modern, colorful and cartoony art style was chosen instead of a pure ASCII-based look, as it is more visually appealing, especially for more casual and younger players. Also, compared to traditional ASCII-based roguelike games, all actions in *Brain Hero Wanderer* are animated (such as battles or consuming items), making it easier for players to understand what is happening on the screen.

Figure 4.3: A screenshot of *Brain Hero Wanderer* of the equipment menu, showing a ring equipped (marked with an "E"). Also, the collected gem pieces are listed.

4.2.1 Core Mechanics

Brain Hero Wanderer follows the usual roguelike mechanics to drive player experience: the player character, the Brain Hero, progresses through multiple randomly generated dungeons, fights monsters in turn-based battles, has to take care of inventory management, and must start from the beginning when losing a run. However, changes have been made to the standard roguelike formula to maintain a much simpler, but nonetheless deep, gaming experience on mobile devices, as the game primarily aims to target casual gamers.

The controls of the game are kept relatively simple and intuitive to enhance the accessibility of the game. The player can only perform a limited number of actions per turn, such as moving, attacking, using items, or throwing items at opposing monsters. This differs from the design decision of many classic roguelikes (such as *Rogue* or *NetHack*), which tend to have a large number of commands and require the study of various key bindings (or key combinations) to learn the game mechanics [80]. All actors in the game also have, for simplicity reasons, only a few attributes, namely attack, defense, speed, health points, and awareness (a set distance the actor can see, also known as field-of-view). However, Figure 4.4 shows that the player character also has additional stats, which can change during the game: Strength, *Attack+*, and *Defense+*, with Strength being a value that augments the player character's offensive power, and the latter two stats indicating how much the offensive and defensive power of the player character has been changed by equipment. The base attack and defense stats of all actors are primarily immutable and are not displayed in-game; only the base attack of the player character can be increased when they level up. The speed stat determines how often an actor can move per turn. For instance, if a monster has a lower speed than the player character, it moves only once every two turns.

Figure 4.4: A screenshot of *Brain Hero Wanderer* showing the profile and stats (Strength, *Attack+*, and *Defense+*, among others) of the player character, respectively.

Generally, the main focus of the game is on various complex interactions of the player with the game world as well as tactics-based gameplay, which is meant to be reminiscent of chess and to become more intense the further the player progresses in the game. The game demands the player to learn about the game mechanics successively by experience before making significant progress. In this sense, the permadeath feature is not intended to be a complete loss for the player.

There are primarily items in the game that do not deal direct damage but rather have a unique effect. These allow for different kinds of interactions, for instance, swapping places with an enemy, pushing back an enemy, or causing status conditions (a typical mechanic for RPGs) such as poison or blindness. Items can also be thrown at monsters so that items do not only have a single purpose, with various kinds of effects (i.e., some monster species are immune to poison status effect when they are thrown with the *Poison Herb* item). Ultimately, the player's decision-making skills should be challenged.

4.2.2 User Interface

Since the game was developed for mobile devices, a virtual analog stick was implemented as a means to control the player character. It was placed at the bottom left of the screen, as shown in Figure 4.4 and Figure 4.2, respectively. The analog stick enables players to move in eight directions by dragging it on the touch screen; diagonal movements are also possible. Furthermore, there are various actions in the game the player can perform, such as attacking, opening and viewing the profile and inventory, and turning around on the spot. The player can perform these actions by using four buttons placed on the lower right side of the screen. The symbols on the buttons are intended to make it as straightforward as possible what they stand for and what action is performed when they are pressed.

The game's user interface also shows the dungeon map one is currently on (F stands for "Floor"), the player character's current level, the actual number of health points (HP) as well as the number of collected cookies.

Additionally, Figure 4.5 shows an interactive tutorial level that was designed to teach players about the mechanics and interactions of the game, including the use and meaning of the four action buttons, without revealing any parts of the main game. Each time a new floor is reached or a certain action is performed in the tutorial level, a text box with an explanation is displayed: The controls and buttons, respectively, are described straight after entering a new level, whereas the actions are explained directly after they have been performed (for instance, when the player character reaches level two).

Another central UI element in the main game is the mini-map which is overlaid over the center-left part of the screen. It is a small and simplified form of the current dungeon map and displays the areas that were already explored, as well as the player, monsters, and collectible objects as yellow, red, and blue dots, respectively. In addition, it reveals the rooms and hallways of the dungeon the further the player advances, preventing them from becoming lost.

Figure 4.6 shows the main menu of *Brain Hero Wanderer*. It has been designed so that it provides an easy and intuitive way to navigate between the different game modes (the main game and the tutorial level) and the ranking, which shows the player's top-five runs in terms of score. In the settings, current language of the game can be changed, from English to German and vice versa. Furthermore, the volume of the background music and the sound effects can be adjusted there.

Figure 4.5: A screenshot of *Brain Hero Wanderer* showing a part of the tutorial level.

4.3 Technical Details

The game was implemented in Unity[1] 2020.3.19f for Android and iOS smartphones using the C# programming language. Unity was chosen as the development tool as it is one of the most popular and established game engines and is commercially available. It has strong out-of-the-box support for a variety of platforms such as Windows, Android, iOS, OS X, Xbox, and PlayStation. Some of the best-known games developed with Unity include Ori and the Blind Forest[2], Pokémon GO[3], and Among Us[4]. The game engine is especially popular within the mobile sector, employing powerful tools and features which facilitate the development and deployment of games for mobile devices. According to the company, more than 50 percent of newly created mobile games are made with Unity [81].

Brain Hero Wanderer makes particular use of two more up-to-date features in Unity, namely *Addressables* and *2D Lights*. Addressables provide a means to separate the asset management concerns from other aspects of the engine, allowing assets to be easily referenced and loaded into memory whenever they are needed. Since different monsters and collectible objects appear in the game depending on the player's progress, there is no need to load all of them into memory at startup. Instead, only assets that occur in the current game

[1]https://unity.com, accessed March 13, 2022
[2]https://www.orithegame.com, accessed accessed March 13, 2022
[3]https://pokemongolive.com/en, accessed accessed March 13, 2022
[4]https://www.innersloth.com/games/among-us, accessed accessed March 13, 2022

Figure 4.6: A screenshot of *Brain Hero Wanderer* showing the main menu.

world are loaded into memory and released again when they are destroyed, improving the overall performance of the game. The integration of the Addressables feature helped speed up the loading of the game worlds, especially on mobile devices. On Android smartphones, where the game was initially tested, the waiting time between transitioning from the title screen to the actual game went down from initially seven to eight seconds to approximately three seconds.

The Addressables system was also used to realize localization via the *Localization* package. Both an English and a German version of the game were created in order to reach the largest possible target group.

The 2D Lights feature allows sprites (i.e., two-dimensional images) to be lit by lights, which was priorly only possible in three-dimensional settings. The feature is part of the Universal Render Pipeline (URP)[5] package, and was integrated mainly for aesthetic reasons, adding more visual detail to the maps and character sprites. URP also allows post-processing effects to be integrated into 2D projects, such as Bloom, but these were not considered due to performance limitations on mobile devices.

The majority of graphics used in the game are obtained from the Unity Asset Store[6] and Unreal Engine Marketplace[7], except for the sprites of the Brain Hero and a few individual

[5]https://docs.unity3d.com/Manual/universal-render-pipeline.html, accessed March 13, 2022
[6]https://assetstore.unity.com, accessed March 13, 2022
[7]https://www.unrealengine.com/marketplace, accessed March 13, 2022

Figure 4.7: A screenshot of *Brain Hero Wanderer* showing 2D light in action.

graphics. The music and sound effects used are license-free and taken from MusMus[8], Pocket Sound[9], and Soundeffect-Lab[10].

During the development of *Brain Hero Wanderer*, attention was paid to ensuring that the game's performance during runtime was optimal, including achieving a frame rate of 60 FPS most of the time. While the implementation-specific measures are discussed in subsection 4.3.1, this paragraph focuses on improving performance by leveraging features of the Unity engine. A key method of improving performance in 2D games was through the use of *Sprite Atlases*. These allow a variety of smaller textures to be combined into a larger texture with uniform size, reducing GPU overhead (or requiring fewer draw calls) to draw the content [82]. Draw calls represent requests to the graphics API (such as OpenGL, Vulkan, or Direct3D) to draw an object in the scene. However, large numbers of draw calls can be very resource-intensive and place a heavy load on the GPU, especially on mobile devices [83]. Therefore, Sprite Atlases provide an effective means to reduce draw calls by combining textures (also known as *batching* [83]) in order to be rendered together.

[8] https://musmus.main.jp, accessed March 13, 2022
[9] https://pocket-se.info, accessed March 13, 2022
[10] https://soundeffect-lab.info, accessed March 13, 2022

4.3.1 Game Architecture

The implementation took the approach of separating the domain logic from the presentation layer, with the presentation layer comprising C# classes that derive from the `MonoBehaviour` class. Generally, C# scripts that inherit from `MonoBehaviour` can be attached to GameObjects in Unity in a scene, thus providing an entry point for the code when the game is started. However, it can be considered a violation of the separation of concerns (SoC) software design principle when a single `MonoBehaviour` script takes on too much responsibility [84]. Hence, for the implementation of the domain logic, pure C# classes were used, which do not derive from `MonoBehaviour`. The game's domain logic is responsible for data management and control flow aspects such as implementing monster and item logic, calculating battle damage, and managing the order of interaction of the actors in the game world. The presentation layer (or view) takes care of, among other things, updating text on the UI and displaying special effects on specific events, for instance, when the player uses items or steps into traps.

The libraries *RogueSharp*[11] and *RogueElements*[12] were used for providing utilities for roguelike mechanics such as field-of-view, pathfinding (RogueSharp), and map generation (RogueElements). As both libraries are developed in C# targeting .NET Standard 2.0, they were easy to integrate into the Unity project. The domain logic of the game is encapsulated by classes that make use of the functionalities provided by the libraries; for instance, the pathfinding functions are used by the monster classes for implementing the monster behavior of chasing the player.

Actions displayed in the view are, for the most part, implemented asynchronously, allowing the execution of code over multiple frames (i.e., in situations where the player character pauses for a specific number of seconds, then an effect or animation is played, and at the end, the controls are released again). Although there is a solution already built-in to Unity in the form of coroutines, which allow for running synchronous code that emulates asynchronous behavior, the library *UniTask*[13] was used instead. UniTask is based on the C# asynchronous programming model, which was introduced with the Unity release in 2017 for the first time and enables a developer to write asynchronous code. The asynchronous programming model features a number of advantages in contrast to coroutines, the most im-

[11] https://github.com/FaronBracy/RogueSharp, accessed March 14, 2022
[12] https://github.com/audinowho/RogueElements, accessed March 14, 2022
[13] https://assetstore.unity.com, accessed March 20, 2022

portant being that asynchronous functions can return values and allow exception handling, as `yield return` statements cannot be put into a `try-catch` block [85].

In some cases, coroutines can have some performance overhead. Therefore, the use of UniTask was considered. The library provides a `struct`-based zero allocation alternative to the C# asynchronous programming model, meaning that the load on the garbage collector is reduced. The garbage collector is a process within Unity's runtime (Mono) that is responsible for periodically releasing unused memory that was previously allocated on the heap. The heap is the memory section where reference-typed objects with an indefinite size, such as classes and strings, are stored. This measure is necessary to prevent the heap memory from constantly growing so that there is enough memory available for the game during runtime. However, garbage collection per se is a costly operation and one cause for performance issues in Unity games, which appear in the form of FPS drops. This is because the Unity engine uses a stop-the-world garbage collector (Boehm-Demers-Weiser GC) that stops the execution of the game when the heap memory is being processed [86]. Even though Unity provides the feature of incremental garbage collection, which allows splitting the garbage collection over multiple frames, thus reducing the number of interruptions [86] and enabling better performance, special care was taken in the development process to allocate as little memory as possible during runtime.

UniTask helped to accomplish this goal due to its features and offered optimal performance. The library can be used insofar as an alternative to Unity's coroutines, as it provides asynchronous-based replacements for all coroutine functions (e.g., `UniTask.Delay` for `WaitForSeconds`).

```
public async UniTask RevealMiniMapAsync(Action onRevealEnd, CancellationToken token)
{
    await ShowFlashAsync(async () => await miniMap.RevealEntireMiniMapAsync(token),
    onRevealEnd, token);
    PlaySoundEffect(SoundEffect.RevealObject);
}
```

Listing 4.1: An asynchronous method for revealing the entire mini-map in the game.

Listing 4.1 shows an example asynchronous method implemented using UniTask, which is realized via the `async` and `await` keywords. It contains the logic for revealing the minimap by first showing a flash of light. At the same time, an asynchronous callback method is invoked and awaited (`miniMap.RevealEntireMiniMapAsync`). At last, when the light flash has finished being shown, the synchronous callback method `onRevealEnd` is called, and an accompanying sound effect is played.

The library *VContainer*[14] was used to implement dependency injection (DI) within the `MonoBehaviour` classes of the presentation layer. Dependency injection is a widely used design pattern in object-oriented programming to improve the maintainability, flexibility, and testability of software by reducing dependencies between classes in a codebase. DI containers leverage dependency injection, allowing to manage all dependencies the classes require at a single place (called the "composition root") and hand these out to the classes at runtime (i.e., the dependencies are "injected"). By obtaining the dependencies from outside, coupling between classes can be kept low, which is an important quality feature in software development.

Using VContainer, dependencies can be injected into constructors, methods, properties, and fields. Since `MonoBehaviour` classes do not support constructors, constructor injection cannot be used. Listing 4.2 shows an example of method injection that is applied to a class in the project. The DI container automatically injects and resolves the dependencies of the class, which are the fields `gameUtility`, `playerController`, and `localizedGameElements`. The `Inject` attribute has to be used to mark a method accordingly for method injection.

```
[Inject]
private void Construct(GameUtility gameUtility, PlayerController playerController,
    LocalizedGameElements localizedGameElements)
{
    this.gameUtility = gameUtility;
    this.playerController = playerController;
    this.localizedGameElements = localizedGameElements;
}
```

Listing 4.2: An example of method injection using *VContainer*.

[14] https://github.com/hadashiA/VContainer, accessed March 21, 2022

4.4 Game Analysis

This section will thoroughly analyze *Brain Hero Wanderer* with respect to the design guidelines presented in Chapter 3.

Category	**Fulfilled?**	**Details**
Low to Moderate Stimuli	✓	The game is graphically minimalistic. For example, there is not a great variety of tiles in the dungeon maps. Even though there are various animations and effects, they are generally only played for a short time. The sound effects in the game are just as purely functional. During development, attention was paid to ensure that the background music was not intrusive, but enhanced the atmosphere of the game.
Dynamic Stimuli	✓	In the game, fanfare sounds are played when the player achieves certain things, such as leveling up or collecting a gemstone. Animations are also shown throughout the game, like in battles. There are virtually no static graphics in the game, except for some UI elements.
Minimum Transition Times	✓	There are no long transition times between game states, especially when loading new dungeon maps. With the help of the Addressables feature in Unity, wait times could be kept to a minimum even on mobile platforms.
High Customizability	∼	The game is not directly oriented to the individual abilities and needs of the child because, for instance, there is no choice of difficulty level. Instead, it is about getting better and better through repeated play and learning through failure and adaptation. However, especially for children, who might have a harder time playing the game, care was taken to offer the most accessible possible entry; for example, a tutorial level was implemented. In addition, the first two levels of the game have been implemented in such a way that they are comparatively easy to manage.

Clear Goal	✓	There is a clear objective in *Brain Hero Wanderer*: collect the seven pieces of the Gem of Gaia to restore the energy of the protagonist's UFO, defeating monsters that hinder their path. The game itself also explains what the goal is and how it can be accomplished.
Avoiding Negative Scores and Text	✓	There are no negative scores in the game (i.e., no point deduction for mistakes). There is also no negative text displayed throughout the game, at most when the player character is defeated in the game.
Focus on Repeatability and Predictability	✓	The game places high value on replayability, i.e., each playthrough is different due to randomization. Thus, every run offers opportunities to learn about the game and its mechanics, which also affects predictability. For example, the player can learn about the strengths and abilities of the enemy monsters to be better prepared for future runs.
Progression During Game Play	✓	It is possible to progress in the game, and the difficulty level slowly increases as the player progresses so that the player remains challenged. The growth of the player character is directly related to the progress in the game. There is immediate feedback, which serves to keep the player engaged and motivated. However, this point is also a matter of opinion due to the permadeath mechanic that leads to a loss of progress if one loses a run.
Less Story Elements	✓	As described in Section 4.1, there are hardly any story elements in *Brain Hero Wanderer*, so the focus is purely on the gameplay. There is only a backstory told at the beginning of the game to give context to the game per se.
Character Customization	∼	Since the game character is already "predefined", one can only give it a (one's own) name. Character customization in the sense of creating an image of oneself in the form of an avatar, as propagated in the design guidelines, does not exist.

Elements of Surprise	✓	The randomization and variation present in the game provide for an unknown surprise factor. Thus, during development, attention was paid to ensuring that there would be enough content in the game to keep the player engaged. Accordingly, there can be surprises, even if the player has played the game for a while. A balance between predictability and surprise is maintained.

Table 4.1: Table showing the game analysis.

Chapter 5

Methods

This chapter describes the aim of the research and the methodological approach employed to evaluate whether the game *Brain Hero Wanderer* is responsive to the needs and preferences of children and adolescents with ASD. This included conducting a qualitative user study including a usability test to evaluate the usability and acceptance of the game altogether. The study was conducted in cooperation with the Austrian company MyMind GmbH[1], and all parents of the participants gave their written consent after the study procedures were explained to them in detail.

5.1 User Study Design

The user study was based on the following two research questions that were to be examined:

- The target group, children and adolescents with ASD, like to play the game. There are no moments where they give up, get angry, or are overwhelmed. Furthermore, there is always something new in the game that motivates them to continue. This is also an indicator that the design guidelines presented in Chapter 3 were indeed adhered to.
- The game can be beneficial to the child or adolescent with ASD (e.g., for their development or life in general). This aspect is determined by asking their parents to answer a corresponding question after their child's playing sessions.

The user study design included an introduction that points out the motivation and the purpose of *Brain Hero Wanderer* to the participants and their parents and briefly explains

[1]https://mymind.life/, accessed April 24, 2022

the game. It served to answer any questions, in particular with respect to data protection of the participant. The content can be found in Appendix B.

5.2 Participants

To find participants, 30 people were initially contacted via e-mail, where six of whom came forward and were interested in letting their child with ASD (they all have an ASD diagnosis) participate in the study. However, two people dropped out during the study. Hence, four participants with ASD were enrolled in the study. All were male, while the youngest was 11 years old, and the two oldest were 16 years old. The fourth participant was 14 years old. All four participants completed the study.

No concrete details were collected regarding the ASD symptoms of the participants. However, some parents have stated in written correspondence that their child suffers from Asperger's syndrome or a high-functioning ASD. The parents of the 11-year-old child had initial concerns about whether he would even be able to fully perform the main objective of the game (exploring all levels in the game, including collecting all gemstones) due to a short attention span. One 16-year-old participant maintained contact with the researcher themselves to some extent and also played the game on his own smartphone.

5.3 Materials and Procedure

Data were collected through a questionnaire to be filled in after playing *Brain Hero Wanderer* for two weeks, for at least 10 to 20 minutes a day, depending on interest. However, the participants were free to manage their time as they wished. The questionnaire, which can be found in Appendix A, included questions regarding demographic data, gaming habits of the participants, and a *SUS* (System Usability Scale, [87, 88, 89]). The SUS is a ten-item scale that is considered a well-established means of measuring the usability of software systems. For the SUS questions, efforts were made to keep the language of the questions simple enough for the corresponding young target group. The questions were mainly taken from the original SUS. However, since this study is intended to test the usability of a game and not that of a software system, they were adapted accordingly. Further, the original questions "*I found the various functions in this system were well integrated.*" and "*I thought there was too much inconsistency in this system.*" were replaced with "*I think that the different* *graphics and styles are well integrated.*" and "*I found that the game had flaws in the game design.*", respectively.

In the questionnaire, the participants were also asked about their overall impression of the game: whether they generally enjoyed the game, were not frustrated or overwhelmed during gameplay, liked the graphical presentation, and how long they actually played the game (in number of days). Responses to these questions (except the latter) were on a Likert scale ranging from one (strongly disagree) to five (strongly agree). Furthermore, there were free-text questions where they could suggest improvements, and point out issues, that they especially liked or disliked while playing *Brain Hero Wanderer*. Finally, concluding the survey, both parents or one parent were asked to answer the question of whether or not the game could be beneficial to their child, with the question also being on a Likert scale. The questionnaire was answered online through the survey platform *Google Forms* [90]. Data were collected only through the questionnaire and not in the game itself. All data were strictly anonymized, with no possibility of assigning data records to a person.

Interested parents were sent either the Android or iOS version of the game. The user study was organized entirely remotely due to the ongoing COVID-19 pandemic.

5.4 Data Analysis and SUS Evaluation

Simple descriptive statistics were used for the analysis and illustration of the data set, such as mean and standard deviation. *R* [91] and *RStudio* [92] were used to perform all analyses and create the graphs. However, since the sample size of this study is very limited (n=4), the study results should be treated with consideration and caution.

The usability evaluation of the game employing the System Usability Scale (SUS) was performed as proposed by literature [87]. The Likert scale values of the negatively-worded questions were subtracted from 1, and those of the positively-worded questions were subtracted from 5. The results were then added together and multiplied by 2.5. The resulting value is the SUS score, which ranges from 0 to 100, where higher scores indicate better usability. An SUS score of 68 is regarded as average [89].

Chapter 6

Results

In this chapter, the results of the user study are presented. As outlined in Chapter 5, the most important variables to be examined are fun or pleasure, frustration or overwhelm, replayability, and the potential benefit of the game to the child or adolescent.

Each individual section of the questionnaire is addressed in detail: demographic data (age, gender), general game preferences, gameplay experience with *Brain Hero Wanderer*, usability assessment of the game, open-ended questions, and both parents' or one parent's assessment of whether the game could be beneficial to their child.

For the purpose of this chapter, participants were given identifiers from **P1** to **P4**. In order to better distinguish them from each other, they are briefly described in the following listing. This listing also describes the demographic data that were entered by the participants in the questionnaire.

1. **P1**: 11 years old, male, Asperger's syndrome
2. **P2**: 14 years old, male, high-functioning ASD
3. **P3**: 16 years old, male, type of ASD not known
4. **P4**: 16 years old, male, Asperger's syndrome, played the game on his own smartphone

6.1 Game Preferences

The four questions in this section were to be answered with "Yes" or "No" only.

Q1: Do you like playing video games?

The study participants were asked if they like playing video games. All of them agreed that they do.

Q2: Do you play video games every day?

Every study participant except P3 plays video games every day.

Q3: Have you ever played a roguelike game?

P4 had experience with roguelike games prior to playing *Brain Hero Wanderer*, while the rest of the participants had no exposure to the genre at all.

Table 6.1 summarizes the answers of the participants.

	P1		**P2**		**P3**		**P4**	
Questions	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Do you like playing video games?	✓		✓		✓		✓	
Do you play video games every day?	✓		✓			✓	✓	
Have you ever played a roguelike game?		✓		✓		✓	✓	

Table 6.1: The results of the first three questions in the *Game Preference* section.

6.2 Gaming Experience

The first three questions in this section asked the participants to rate the extent to which they agreed with each question on a Likert scale from one (strongly disagree) to five (strongly agree). The fourth question included an input field where participants could enter the number of days they played the game.

Q1: Did you enjoy the game overall?

The game was generally well received by the participants. P1 and P2 had fun with the game ("agree"), while P3 had a neutral view of it. P4, on the other hand, found the game to be very enjoyable ("strongly agree").

Q2: Did you feel frustrated or overwhelmed while playing?

The question of whether one felt frustrated or overwhelmed while playing *Brain Hero Wanderer* represents one of the central questions of this research. The results were mostly positive: only P3 felt frustrated or overwhelmed ("agree"), whereas this was not the case for all the other respondents. P2 and P3 did not feel frustrated or overwhelmed ("disagree") during game play, while there was no frustration or overwhelm at all for P1 ("strongly disagree").

Q3: Did you like the graphics of the game?

The graphics of the game were found to be very appealing overall. P1, P2 as well as P4 liked the graphics a lot ("strongly agree"), with only P3 having a neutral view on it.

Q4: How often did you play the game (in number of days)?

When asked how often participants played the game in number of days, the average was $\bar{x} = 12$ ($s = 1.63$). More precise data were available from P1 and P4. P1 played the game for at least 20 minutes on 12 days, while P4, who played it on his own smartphone, stated that he played the game for about 2 hours (instead of the predetermined 10 to 20 minutes) a day, and even spent five hours playing on the first two days.

As it can be seen in Table 6.2 below, the game was all in all well enjoyed by the children and adolescents, with a mean value of $\bar{x} = 4$ ($s = 0.82$). The variable of frustration had a mean of $\bar{x} = 2.25$ ($s = 1$), while the graphics per se were very well received, having a mean of $\bar{x} = 4.5$ ($s = 1$).

Figure 6.1 shows the number of days the game was actually played for each participant.

Question	**Rating**
Did you enjoy the game overall?	$\bar{x} = 4$ ($s = 0.82$)
Did you feel frustrated or overwhelmed while playing?	$\bar{x} = 2.25$ ($s = 1.26$)
Did you like the graphics of the game?	$\bar{x} = 4.5$ ($s = 1$)

Table 6.2: The results of the first three questions in the *Gaming Experience* section.

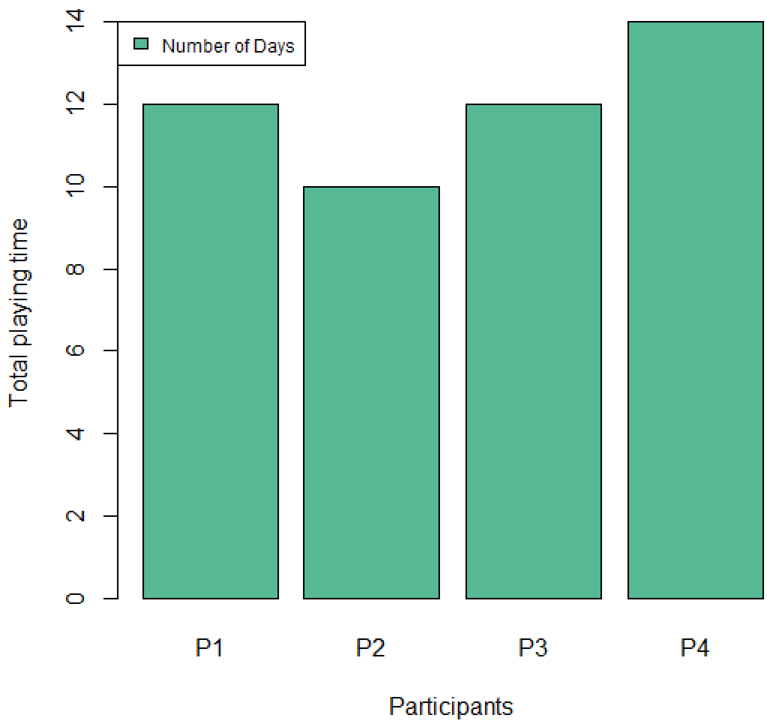


Figure 6.1: The number of days the participants played *Brain Hero Wanderer*.

6.3 Usability Test

The results of the usability test were analyzed according to the described methodology in Chapter 5 utilizing the System Usability Scale (SUS). Figure 6.2 shows the SUS score chart for each participant. In addition, for illustrative purposes, a horizontal dotted line was drawn, which represents the benchmark average SUS score of 68.

The overall average SUS score is $\bar{x} = 63.13$ ($s = 10.87$), which means a slightly below-average usability. The range of the four individual SUS scores is relatively broad, ranging from 47.5 to 72.5.

All in all, the participants can imagine that they would want to play the game on a regular basis, and generally they found the graphics and styles to be well integrated into the game. Further, while the game was easy to understand for the majority of the participants (all agreed with the statement, except for P3, who was neutral about this aspect), three participants still had problems understanding the tasks in the game right away and would have needed more explanations to play the game.

Most participants also agreed with the statement that most children would be able to learn very quickly to play *Brain Hero Wanderer*. Only P3 disagreed with this statement. P4 believed that the game had flaws in the game design, while all the other respondents disagreed. In terms of game controls, P3 agreed that these were very cumbersome to use, whereas this was apparently not the case with the other participants. When asked if the children and adolescents felt safe (or confident) while playing, only P2 gave a neutral answer. The remaining respondents agreed (P3) or strongly agreed (P1 and P4) with the statement.

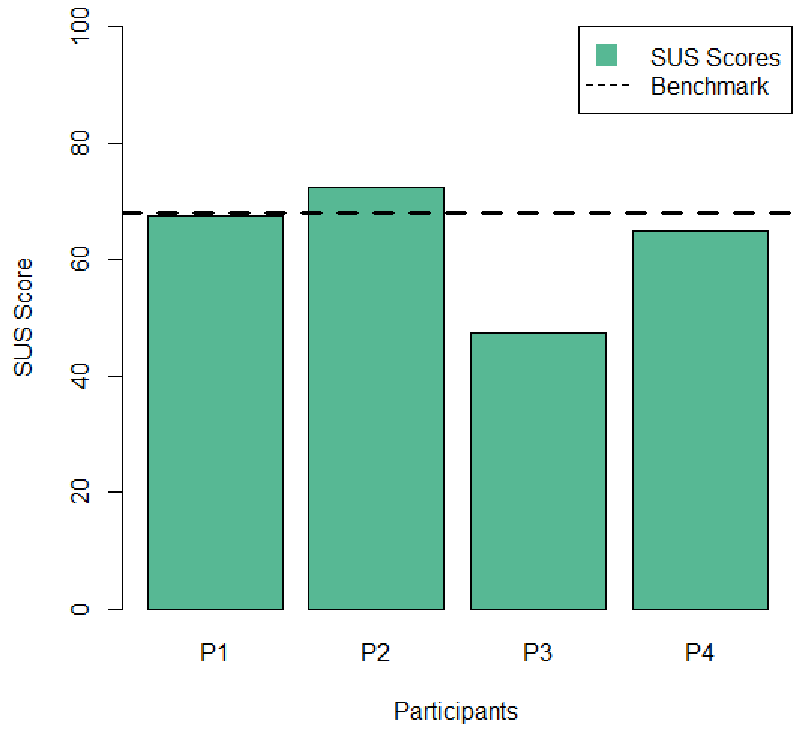


Figure 6.2: The SUS score per participant including a horizontal line representing the benchmark of 68 (the average SUS score).

Since the SUS statements also measured whether the game had replay value for the participants (*"I can imagine playing the game regularly."*), Table 6.3 was created for all statements in the SUS survey, on which the mean and standard deviation for the answers of each item is reported.

6.4 Open Question Responses

Participants had the opportunity to answer the following three open-ended questions:

Statement	**Rating**
I can imagine playing the game regularly.	$\bar{x} = 4.5$ ($s = 0.58$)
I found the game unnecessarily complicated.	$\bar{x} = 2.5$ ($s = 1.3$)
I found the game easy to understand.	$\bar{x} = 4$ ($s = 0.82$)
I think that I need more explanations to play this game.	$\bar{x} = 3.75$ ($s = 1.26$)
I think that the different graphics and styles are well integrated.	$\bar{x} = 3.75$ ($s = 0.5$)
I found that the game had flaws in the game design.	$\bar{x} = 2.5$ ($s = 1$)
I can imagine that most children learn to play this game very quickly.	$\bar{x} = 3.75$ ($s = 1.25$)
I found the controls of the game very cumbersome.	$\bar{x} = 2.75$ ($s = 0.96$)
I felt very safe while playing the game.	$\bar{x} = 4.25$ ($s = 0.96$)
I did not understand all the tasks in the game right away.	$\bar{x} = 3.75$ ($s = 1.26$)

Table 6.3: The results to the statements in the *Usability Test* section.

- Q1: What did you like most about *Brain Hero Wanderer*?
- Q2: What did you not like about *Brain Hero Wanderer*?
- Q3: If you could improve *Brain Hero Wanderer*, what would you do?

All questions were answered by the participants, despite them being only optional. What is worth pointing out is that every participant mentioned aspects about the game that they found positive, even if they were not necessarily fond of the game.

P1 liked the suit of the Astronaut, a monster that frequently appears on the first two floors of the game. P2 stated that he liked almost everything about the game and emphasized that it never felt boring. P3 enjoyed collecting "treasures" (i.e., items, equipment, and cookies that are scattered around the game world) and exploring randomized maps, whereas P4 liked the graphical style of the game, the large number of useful items, and the soothing music.

The points that stood out negatively about *Brain Hero Wanderer* were varied. P1 had problems with the randomization mechanic at one point: he was chased and attacked by three opponents at the same time right after starting a new game and quickly lost a run. For P2, the game sometimes became too hard, which is also related to the randomization aspect of the game. P3 did not like the roguelike-specific core feature of permadeath. His specific feedback was that the game progress was not saved, having to start all over again after a lost run. He also had problems with the size of the control buttons on the screen. P4 stated that there were minor bugs. Aside from that, similarly to P1, he had the issue when multiple monsters spawned next to his player character after starting a new game, in a situation when he could have been able to collect a useful item.

Regarding Q3, the suggestions for improvement, P1 wished for "more cool maps". P2 thought that the game was already good as it is and stated that it did not need any improvements. P3, who also did not like the graphics of the game, would improve the graphics and make the control buttons on the bottom right side of the screen bigger. P4 would improve the usability of the joystick (i.e., the virtual analog stick on the bottom left) and fix the game freezing bug that occurred to him during gameplay.

Table 6.4 shows a summary of the participants' responses to the open questions.

6.5 Question for Parents

A further essential aspect of this research is also the question of whether the parents of the participating children and adolescents find *Brain Hero Wanderer* to be beneficial to their child. For this purpose, there was a corresponding question in the questionnaire that they were asked to answer. The question was, like those in the *Game Experience* section and in the usability test, also in the form of a five-point Likert scale.

Generally, three out of four families felt that the game could be of value to their child ("agree"). Only the parents of P3 gave a neutral statement. The mean result and standard deviation can be seen in Table 6.5.

Question	Participant	Statement
Q1	P1	I liked the Astronaut's suit.
Q1	P2	I liked almost everything. The game doesn't get boring.
Q1	P3	I enjoyed collecting treasures and moving to new random maps.
Q1	P4	I liked the graphical style, all the useful items, and the soothing music.
Q2	P1	I didn't like the part where I started a new game and there were three enemies attacking me, which made me lose fast.
Q2	P2	Sometimes the game gets too hard.
Q2	P3	The game doesn't save progress. Every time I failed I had to start all over again.
Q2	P4	I didn't like minor bugs that were happening. Other than that, there was also a problem when I started the game, monsters spawned next to me. That's pretty RNG because sometimes you can get items next to you.
Q3	P1	I wish they had more cool maps.
Q3	P2	It's already a great game. I don't think it needs any improvements.
Q3	P3	Improve graphics. Make control buttons bigger.
Q3	P4	Make the joystick a little more usable and fix the freezing game issue.

Table 6.4: The responses of the participants to the open questions.

Question	Rating
Do you think this game could be beneficial to your child?	$\bar{x} = 3.75$ $(s = 0.5)$

Table 6.5: The result of the question asked to parents.

Chapter 7

Discussion

7.1 Summary

Many studies use a wide variety of technologies to treat children and adolescents with autism spectrum disorder (ASD). These are primarily aimed at compensating for their deficits in the area of interpersonal relationships (i.e., social interaction and communication) and improving their mental health. These technologies include, for instance, serious games for learning new skills or enhancing emotion recognition and facial identity recognition, interventions that make use of virtual reality technologies, or robotics. However, there are comparatively very few studies in which participants try an entertainment computer or mobile game and then give their feedback on whether they liked it, would play it for a longer period of time, or whether it could be beneficial to them (e.g., for their development or daily life in general). The majority of existing studies are medical intervention studies.

The main research questions of this master's thesis addressed the examination of the needs, preferences, and strengths of children and adolescents with ASD. These can differ greatly from child to child, as ASD per se is a very complex diagnosis (hence the collective term autism spectrum disorder for a wide variety of manifestations). The needs of children and adolescents with ASD are often interpersonal relationships, communication, and participation. However, these are more difficult to satisfy due to their ASD-specific characteristics. It is also feasible that some affected individuals may not even feel the need for communication. Further needs include recreation, compensation, and fun. There are, however, limited recreational opportunities for children and adolescents with ASD. A cause for this is, in many cases, their symptomatic increased sensory sensitivity.

Therefore, these needs can be accommodated by the use of screen-based media, including video games, as many studies reviewed in Chapter 2 have shown. The review also indicates that individuals with ASD do indeed appear to have a pronounced affinity for screen-based media. Video games in particular can provide an immersive, predictable, and safe environment for this target group, potentially promoting compensation and relaxation. Furthermore, the child or adolescent may block out unwanted environmental stimuli by playing video games (or through the use of screen-based media in general). Durkin et al. [41] stated in their research that video games may have a positive social impact on children and adolescents with special educational needs (including individuals with ASD), as they are also interested in fun and socializing like their typically developing peers. For instance, it was reported that some children and adolescents with ASD began to develop an interest in video games that were popular with their peers, despite some of them not being accepted in social situations [41]. Therefore, video games may help affected individuals to feel part of a group or socially accepted. Screen-based media may provide the possibility of a sense of belonging. In this way, the need for communication and participation may also be satisfied. Durkin et al. [41, p. 84] asserted that "work with children with ASD indicates potential for supporting and improving understanding of other people via games [...]".

Also, screen-based media may appeal to ASD children and adolescents due to many of them having strengths in visual perceptual skills [51, 52].

As examined in the literature review in Chapter 2, studies have also shown that serious games, virtual reality environments as well as computer-assisted instructions (CAI) may offer a viable opportunity to overcome some social problems and acquire social skills in children and adolescents with ASD, for example in mutual communication. These individuals also tend to have cognitive difficulties and learning disabilities. The associated needs are referred to as "special educational needs" in the Durkin et al. [41] study. To this day, however, research is still being conducted in these areas of technology, especially since there are also studies, particularly in the field of virtual reality (e.g., [64, 65]), that report only moderate effectiveness of the technology.

Section 2.5 of Chapter 2 addressed the potential negative effects of computer games on children and adolescents with ASD, which should not be disregarded. This mainly concerns the genres of shooters and role-playing games (RPGs). The study conducted by Mazurek and Engelhardt [48], which looked into video game use and problematic video game play patterns in boys with ASD, found that adolescents who preferred to play shooters and RPGs on the computer are more likely to consume these games in a problematic (i.e., oppositional or addictive) manner compared to their typically developed peers. The authors pointed out that children with ASD in general may have a potential higher risk for developing problematic or addictive game play behaviors. Therefore, with regard to this aspect, it is also important for parents to accompany or monitor their child.

The design guidelines for computer games aimed at children (and also adolescents) with ASD, elaborated in Chapter 3, were developed with the aforementioned problematic behaviors in computer games in mind. These guidelines were primarily inspired by the study from Bartoli et al. [72], but with the difference that the guidelines of this master's thesis do not refer to serious games as in the study but to entertainment games. Therefore, some points were adapted, or own points were introduced. The design guidelines of Chapter 3 also aim to address the video game preferences of children and adolescents with ASD (e.g., predictability). To the author's knowledge, design guidelines that focus on the development of entertainment games for young individuals with ASD are novel.

Additionally, as part of this master's thesis, the game *Brain Hero Wanderer* was created as a proof-of-concept project, which was developed on the basis of the design guidelines. It is a full-fledged game for smartphones (Android, iOS) that is relatively extensive. It was important to include a lot of content in the game, as it should keep players engaged and entertained for a long period of time. A user study was then conducted with affected children and adolescents to evaluate whether the game actually adhered to the design guidelines, and if it was well received by the participants overall and they would indeed play it for an extended period of time. In order to find out if the game meets their needs (e.g., fun, compensation) and preferences for video games, there were open-ended questions that the participants could answer. In addition, the parents or one parent of the participants were also asked if they thought the game could be beneficial for their child.

Initially, the corresponding question in the questionnaire was *"Did you notice any positive changes in your child after the experiment?"*. However, this would have counted the study as an intervention study, which would have had to be approved by an ethics committee and would have been complex to organize. Consequently, this question was discarded and replaced with *"Do you think this game could be beneficial to your child?"* so that the study could remain a user study.

As the game *Brain Hero Wanderer* is a roguelike title, thus an entertainment game rather than a serious game, the main focus is not on improving players' social skills. It is primarily intended to be enjoyable, fun, and ideally beneficial in the longer term. Although the roguelike genre is a subgroup of RPGs (which, as mentioned earlier, can make for problematic video game use), the genre was chosen due to its stronger emphasis on gameplay, having no actual storyline. Further, the gameplay is comparatively simple, with one goal that carries through the game. Since randomization is a key aspect in roguelike games, this adds replay value at the same time, making each run in the game different. By playing the same levels over and over, predictability is ensured, while randomization also brings something new and potentially surprising that can motivate players to keep playing.

What is controversial (even among neurotypical gamers) about roguelike games, however, is the permadeath feature, meaning that the game must be started over again upon the player character's death. During the planning of *Brain Hero Wanderer*'s development, it was taken into account that it could lead to frustration for people with ASD, losing all the progress that they have made. However, seeing as permadeath is a core feature in roguelike games, it was necessary to keep it in the game, even though it might not appeal to everyone. The feature helps create the feeling that is special to roguelikes: creating a more immersive gaming experience by putting weight on every decision (roguelikes are traditionally turn-based) the player makes.

It is possible to progress in the game despite the own player character regularly dying because one can, for instance, learn about new tactics or monsters' abilities and movements during gameplay, which lets the player slightly change their play style. Consequently, the player learns to read these threats, thus getting better at the game and progressing further in this way.

7.2 Interpretation of Study Results

The results presented in Chapter 6 show that *Brain Hero Wanderer* was generally well received among the participants. Only P3 found it neither good nor bad. However, P3 does, although he likes playing video games, not play these every day, whereas all the other participants do. Moreover, P4, who found the game very enjoyable, already had previous experience with roguelike games. Otherwise, none of the other participants had any contact points with the genre. In addition to P3, all other participants generally like playing video games.

Further research questions of this master's thesis include the aspects that the game should neither be frustrating nor overwhelming for the players with ASD and should have a positive replay value or long-term motivation. Concerning the participants' gaming experience, P3 had moments during gameplay where he had feelings of frustration or overwhelm. This was not the case with the other participants. According to the participants' evaluation, the replay value of *Brain Hero Wanderer*, which was actually measured during the usability test, is very high, with a mean value of 4.5. Interestingly, even P3, although he felt frustrated or overwhelmed, agreed that he would play the game regularly nonetheless. Additionally, the graphics and graphical style of the game were found to be very good by P1, P2, and P4. Only P3 had a neutral opinion on this aspect.

The cause of P3 having felt frustrated or overwhelm is very likely from his dislike of the permadeath feature. Also, he found the game controls to be very cumbersome. This was not the case for the remaining participants, so it can be concluded that it is not an inherent game design issue but instead that P3 had problems with the buttons on the bottom right part of the touchscreen (these were too small for him) and the genre-typical mechanics, finding them obstructive and complicated.

The SUS scores by P1, P2, and P4 were around average, while that of P3 was significantly below average. It is noteworthy that the majority of the participants either had difficulties understanding the tasks in the game right away or would have needed more explanations to play the game. For instance, just P4 had an easier time understanding the tasks of the game, and that is presumably due to his previous experience with roguelike titles.

Although this was considered a potential problem during the development of *Brain Hero Wanderer*, and a separate in-game tutorial was implemented for this purpose, these difficulties still arose. However, the tutorial was only optional to complete and at most described the individual game elements of the game (e.g., monsters have to be attacked to move forward in the game, items and equipment have to be used from the inventory) and let the player play a relatively easy level in terms of difficulty, without explaining the overall objective and goal of the game. The mechanics of the game were not brought closer to the player in detail. These issues should be revised in a potential future release of the game. Nonetheless, the game was easy to understand for the participants (except for P3, who found this neutral). This impression may have been formed among the participants after they had already been playing the game for a while. Also, all participants generally felt confident (the original wording in the questionnaire was "safe") while playing the game. The fact that P3 found the game complicated is also underlined by his disagreement with the statement that most children can learn to play it very quickly. In contrast, the other participants either agreed or strongly agreed with that statement.

Three of four parents (or one parent) agreed that *Brain Hero Wanderer* could be beneficial to their child, confirming that the children and adolescents actually enjoyed the game and had fun playing it. This is also consistent with the findings of Finke et al. [46], who collected surveys from parents of 152 examined children with ASD, reporting that some parents viewed video game play as positive for their child's development. The parents of P3 gave a neutral response, which was not unexpected since P3 did not like the game as much compared to the other participants. What is worth mentioning is that the mother of P1 communicated via e-mail that his 9-year-old brother (who is also diagnosed with Asperger's syndrome) played the game alongside him, which was another positive way for them to bond. She extended her gratitude for allowing her child to have this experience.

Lastly, based on the responses to the Gaming Experience section of the questionnaire, the usability test, and what the participants answered in the open-ended questions, it can be assumed that the design guidelines discussed in Chapter 3 are fitting; exceptions being that subsection 3.2.5 (*Progression During Game Play*) may be seen differently by players who do not prefer the roguelike feature due to the permadeath feature. One further point regarding game controls, included both for mobile and computer games, could also be added to the design guidelines, considering that two participants mentioned having issues with the controls in *Brain Hero Wanderer* (especially P3).

However, due to the limited overall sample of this user study (N=4), it should be kept in mind that the generalizability and external validity of the results to a larger number of individuals with ASD is very limited. It might be of interest to conduct a user study with a larger sample size using a revised version of the game that incorporated the feedback from the four participants.

7.3 Conclusion

This thesis focused on examining the impact of technology- and game-based interventions on children with ASD, as well as their needs and preferences. The current state of research indicates that many young individuals with ASD have a distinct preference for screen-based media, including playing video games. Technology-based interventions have been shown to help improve the social interaction and communication skills in children and adolescents with ASD. Further, video games per se may also contribute to fostering socialization and friendship. Potential adverse effects of video games on this target group were also highlighted, which include addictive and oppositional behavior. Given the increasing prevalence of ASD in the population, it is important to recognize the need for research and resources in this field.

Additionally, this work introduced design guidelines for developing video games aimed at children and adolescents with ASD. To evaluate the validity of the design guidelines, the roguelike game *Brain Hero Wanderer* was developed as a proof-of-concept and tested in a user study by four young males with ASD between 11 and 16. Their parents were also asked about whether the game could be beneficial for their child. The results have shown that, although the study came with the limitation due to the small sample size, the game was well received overall, being fun to play and having a replay value. There was occasional criticism with respect to genre-specific features, the controls, and complexity. Acceptance among the parents was also solid overall.

For future research, the following bullet points could be considered: (1) since the sample size of this user study was very limited, a larger one might provide more meaningful results and exciting findings. An updated version of the game that fixed the issues reported by the four participants could then be used, and (2) the design guidelines presented are not limited exclusively to one genre. Therefore, games of other genres could also be developed based on those. In particular, it might be of interest to examine the research questions of this master's thesis with different kinds of games.

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Appendix A

Questionnaire

Demographic Data

1. What is your age?
2. Your gender? (male/female/other)

Gaming Habits

1. Do you like playing video games?
2. Do you play video games every day?
3. Have you ever played a roguelike game?

Gaming Experience

1. Did you enjoy the game overall?
2. Did you feel frustrated or overwhelmed while playing?
3. Did you like the graphics of the game?
4. How often did you play the game (in number of days)?

Usability

1. I can imagine playing the game regularly.
2. I found the game unnecessarily complex.

3. I found the game easy to understand.
4. I think that I need more explanations to play this game.
5. I think that the different graphics and styles are well integrated.
6. I found that the game had flaws in the game design.
7. I can imagine that most children learn to play this game very quickly.
8. I found the controls of the game very cumbersome.
9. I felt very safe while playing the game.
10. I did not understand all the tasks in the game right away.

Open Questions

1. What did you like most about Brain Hero Wanderer?
2. What did you not like about Brain Hero Wanderer?
3. If you could improve Brain Hero Wanderer, what would you do?

Question for Parents

1. Do you think this game could be beneficial to your child?

Appendix B

Information Sheet

What is Brain Hero Wanderer?

Brain Hero Wanderer is a so-called roguelike game, a subgroup of role-playing games (RPGs). The objective of the game is to explore 17 game worlds (dungeons) and to find and collect seven jewel pieces. The dungeons consist of many randomly generated rooms containing treasures and monsters. Due to the random generation, no two playthroughs are the same. There is a "permadeath" feature, meaning that if the player character dies, the game must be started over again. The combat system is turn-based, and the player can learn the monsters' movements to be better prepared for the next attempt. However, the monsters get stronger the further the player advances into the dungeons. Thus, strategy is required to win the game.

What is the motivation behind the project?

For a master's thesis, guidelines for the development of games targeted at children and adolescents with autism were developed, which are now to be evaluated through the game. The main aim is to determine whether the game is well received by the target group and whether it is fun for them and, in the best case, also beneficial.

What does my child have to do in this user study?

In this user study, children should play the game for 2 weeks, for about 10-20 minutes a day. The playing time could also be longer, but it is more important that the game is played daily for two weeks. In this regard, rather short sessions are recommended, which are reliably completed every day.

What data are collected?

No data are collected in the app itself: in particular, coveted Apple Ad IDs/GA IDs (codes with which Apple/Google identifies the user for advertising purposes) are not read by the app. Meta information about the smartphone also remains unaffected.

The attached questionnaire is for statistical evaluation only. All data are strictly anonymized, with no possibility of assigning data records to a person.

Does the game contain advertisements or are there any costs for the participants?

The game is 100% free. It does not contain advertisements, microtransactions and paywalls.