Designing Neurogames to Support Patients under Psychotherapy Treatment: Opportunities and Challenges of the MUSE Headband

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Abstract: In childhood and adolescence, mental development processes are crucial for a person's long-term, cognitive health. Many young people have at least one characteristic that leads to psychological impairment and must be accompanied by therapy. Therapy success requires the constant execution of therapeutic exercises during and after therapy sessions. However, keeping the motivation of the patients upright for continuous cooperation is a key challenge, since the exercises are perceived as laborious. A digital, playful training application offers the potential to support the therapy of children and adolescents. Measuring brain activity plays an important role as it shows how good patients can push away negative thoughts affecting their mental disorder. For this purpose the fundamentals of serious games, neurofeedback, brain computer interfaces (BCIs) and electroencephalography (EEG) as well as different therapy-accompanying measures were examined. Based on the findings and a focus group with psychotherapists (N=3), a serious game was designed as a motivational concentration and attention training to support psychotherapy. During the game the easy-to-use MUSE headband measures concentration and integrates neurofeedback as a game mechanic. User tests with children (N=21) were performed to evaluate the developed prototype and gather further information on usability, technology acceptance and playfulness of the neurogame.

1 INTRODUCTION

Mental disorders are global public health issues. They account for more than 10% of the global burden of disease (Vigo et al., 2016) and no fewer than 800,000 people die each year as a result of suicide (World Health Organization, 2018). The number of people under the age of 15 who suffer from depression has increased significantly in recent years and has increased more than tenfold compared to the year 2000. According to Naab et al. (Naab et al., 2017) a nationwide study in Germany of 2,863 families with children aged 7 to 17 years showed that 14.5% of the children had characteristics of at least one impairing mental health problem. Same or even higher percentages across Europe up to 27.9% in Bulgaria were shown by Husky et al. (Husky et al., 2018). However, less than half of the children received therapy or the parents considered it in need of treatment. Typical disorders that occur in young children are: post-traumatic stress disorders, depressive disorders, attention deficit / hyperactivity disorders (ADHD), anxiety disorders, autistic disorders, attachment disorders and sleep disorders. Successful therapy can only be achieved through careful and independent implementation of therapy-accompanying exercises. However, many patients do not perform their exercises regularly because they find the tasks tedious or boring (Mader et al., 2016). Accompanying and supporting measures, which are used in psychotherapy to reduce symptoms, are mindfulness exercises, relaxation procedures as well as concentration and attention training. These measures are used to treat a wide range of mental illnesses and have been proven through studies. However, the patient lacks motivation to carry out the exercises continuously, since therapeutic success does not occur immediately. In order to enable treatments for the large number of young patients and to motivate them to carefully carry out exercises accompanying therapy, motivational, target group-specific support of the therapy is required. Here, the use of electronic devices offers the potential to close gaps in therapy and to open up new treatment options or to supplement existing ones. Chapter 2 introduces background information about neurofeedback, Brain Computer Interfaces and Serious

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Game Design. Chapter 3 outlines the conducted research method. Chapter 4 presents the findings, chapter 5 discusses results and chapter 6 summarizes results and gives ideas about future work.

2 BACKGROUND

According to Li et al. (Li et al., 2014), a lot of research has been done in recent years to develop new and inexpensive technologies that can be used to treat mental health. Digital applications such as serious games can be used as a therapy-accompanying measure and motivational incentive to support the therapy of children and adolescents with different mental illnesses. Thereby therapeutic effects can be achieved by training certain skills as well as conveying psychotherapeutic content. Such games have been used successfully in psychotherapy to treat various mental disorders. The success of serious games in the context of therapy lies primarily in their ability to increase therapy compliance and motivate patients to independently carry out therapy-supporting exercises at home (Brezinka and Hovestadt, 2007; Fernandez-Cervantes et al., 2015). In addition, they offer the potential to convey psychotherapeutic content in a playful way and thus increase the learning success in exercises accompanying therapy. When performing such exercises, various physiological effects occur, which can be recorded with the help of neurofeedback devices (Goldbeck and Schmid, 2003; Forsner et al., 2014).

2.1 Neurofeedback

Today, neurofeedback is considered a scientifically recognized method for optimizing brain activity by minimizing or maximizing certain activities. Studies have shown that patients with various mental disorders have brain activities that differ from healthy people. A large number of disorders, diseases and unwanted behavior patterns can be attributed to incorrect regulation of brain activity (Fiałek and Liarokapis, 2016; Sourina et al., 2011). Neurofeedback is measured with Brain Computer Interfaces (BCIs) and displays patient brain activity in real time. As part of neurofeedback training, the patient should learn to control his brain activity and to consciously change it. Neurofeedback training is intended to teach the patient how to regulate abnormalities in his brain activity himself (Heinrich et al., 2007). The user can receive various feedback about his internal status. According to Hammond (Hammond, 2011),neurofeedback has been used in clinical and research applications for decades to treat patients with mental illnesses and has already been used successfully in numerous psychiatric and neurological disorders, such as depression, concentration and memory problems, stress disorders, ADHD and autism. In addition, neurofeedback training can also be used to promote health, preventive measures and improve cognitive performance in healthy people, such as coping with stress or training the memory. This makes neurofeedback training an important treatment method for a wide range of mental disorders as an alternative to medication. Neurofeedback training can be carried out in various forms such as neurogames, simple visual feedback or audio feedback (Liu et al., 2016). So far, there is no generally applicable standard for neurogames. Various works, however, use this term in a similar context as digital games, which use neurofeedback devices, such as brain computer interfaces, for interaction within a game. BCIs measure brain activity and recognize certain brain patterns that can be interpreted and translated into commands for communication with BCI applications. Their use enables the internal state of the user to be included in the game and to provide feedback on physiological processes in the body that are normally not perceptible (Heinrich et al., 2007). In this way, the application can be adapted to the feelings and experiences of the user in order to integrate them more into the game. With the help of neurofeedback within a serious game, awareness of one's own inner state can be developed, self-reflection can be facilitated and mindfulness can be promoted (Sliwinski et al., 2017).

2.2 Brain Computer Interfaces and MUSE Headband

A Brain-Computer-Interface (BCI), also called Brain-Machine-Interface (BMI), is with respect to Graimann, Allison and Pfurtscheller (Graimann et al., 2009), an artificial system that measures the user's brain activity, interprets it and translates it into control signals for BCI applications. Since the measured activity comes directly from the brain without requiring physical movement, it is referred to as the brain-computer interface. A BCI can, according to Graimann et al. not read minds, but classify special activity patterns in brain signals that are associated with certain tasks or events. Brain-computer interfaces represent a sub-category of the so-called "prostheses". These are devices that not only receive output from nervous systems, but can also offer input and thus interact with the peripheral and central nervous system. Brain computer interfaces enable the use of interactive applications by interpreting and translating various brain patterns into control commands (Wolpaw et al., 2002). They enable a new human-computer interaction as an alternative to conventional input devices such as a mouse, keyboard and touch displays and can thus be used by people with serious physical disabilities as a non-muscular means of communication (Graimann et al., 2009; Perales and Amengual, 2017; Sourina et al., 2011). BCIs can also be used as neurofeedback training as a treatment alternative for various cognitive disorders. However, brain-computer interfaces are not suitable for controlling complex applications because their information transfer rate is not sufficient for this. Complex tasks like controlling a robot arm, reaching for a bottle or chatting quickly require more information per second than can be provided by a BCI (Graimann et al., 2009). In addition, so-called artifacts can occur during signal acquisition, which arise as interference in the signal due to other activities and must be removed (Fiałek and Liarokapis, 2016; Graimann et al., 2009). Non-invasive electroencephalography (EEG) is the most widespread technology. It is used to record the electrical activity of the scalp using electrodes. Compared to other BCI technologies, EEGs are inexpensive, portable and offer a reasonable compromise between spatial and temporal resolution (Graimann et al., 2009; Scherer et al., 2017; Vourvopoulos et al., 2017). With the help of an EEG, the electrical potential of the scalp can be measured using surface electrodes. According to Sourina et.al. (Sourina et al., 2011), this potential arises from cerebral cortex activity in the brain and reflects the state of the brain. This makes it possible to recognize emotions, mental states and movement ideas of the user in a non-invasive manner in real time (Sourina and Liu, 2015). The use of EEG technology in various research disciplines has increased in recent years since more and more inexpensive, easily transportable and user-friendly devices have been commercially available which provide sufficient measurement quality (Krigolson et al., 2017; Przegalinska et al., 2018; Scherer et al., 2017). This research focuses on the MUSE headband, as it is an easy to use EEG headband. Studies show that it is also a reliable source for measuring gamma waves as the source of concentration (Krigolson et al., 2017; Przegalinska et al., 2018). Compared to the Mindwave, which is often used as a BCI for neurogames and offers only 1 EEG, MUSE measures brain activity with 7 EEG sensors.

2.3 Neurogames in Psychotherapy

”Harvest Challenge” is a neurogame intended to serve as intention training for children with attention deficit and hyperactivity disorder between the ages of 8 and 13 years. Munoz et al. (Muñoz et al., 2015) decided to use the MindWave neurofeedback headset as part of this application, since it is comfortable for the user to use and requires little configuration time. Harvest Challenge was designed for use in various educational institutions and for neuropsychological care, but should also be usable by children at home. The digital game was developed in an interdisciplinary team of designers, developers, neuropsychologists and psychiatrists and incorporates the internal state of the user into the application with the help of an EEG. The goal of the game is to improve certain skills of the child. This includes patience, planning skills as well as the ability to follow instructions and achieve goals. The improvement of these skills should also lead to an increased learning process as well as an improved control of attention. Within the application, the player controls a boy who lives in a Colombian coffee region and has to perform various tasks in the form of mini-games. The relaxation and concentration level of the user is integrated in different ways for interaction within the game. As part of a mini-game, the player has to select predetermined objects that rotate in a circle. In order to select an object, he must stop the rotation by increasing his attention level when the object is at a predetermined position. Another mini-game is that the player has to collect vegetables. However, this is only possible if the user reaches a certain concentration level and should train him to keep his concentration. At the end, the course of the user's mental activity during the game is visualized by a diagram. So far, no studies on the effectiveness of Harvest Challenge have been published. This application shows how a neurogame for children with ADHD can involve the player's level of concentration in different ways to actively influence the game in order to train the ability to concentrate, while improving other relevant skills. Schoneveld et al. (Schoneveld et al., 2018) as well as Jacob and Teuteberg (Jacob and Teuteberg, 2017) present the game ”Mind-Light” in their work developed by the PlayNice Institute, which also uses the MindWave from Neurosky to include neurofeedback. This is a neurogame for the therapy of children with increased anxiety symptoms. Various techniques such as neurofeedback, confrontation training, and attention modification training are included within the game to train children to deal with their anxiety. In the context of the application, the player takes on the role of a child who wants to save his grandmother from evil forces. Various relaxation techniques are taught to the user within the game. He should also learn that he can overcome his fears by adjusting his state of mind. The relaxation level of the player is included in the application and represented by a shining light, which helps the player to navigate through the game world and defeat opponents. The user must remain as relaxed as possible in order to use light to transform threatening objects and shapes into harmless ones. Schoneveld et al. examined in a study with 174 children between the ages of 7 and 12 whether MindLight is just as effective for the therapy of children with anxiety symptoms as cognitive behavior therapy. Half of the children played the game, while the other half received conventional therapy. Both treatments showed a significant decrease in anxiety symptoms, with MindLight having the same effectiveness as cognitive behavior therapy. MindLight thus proved to be an effective measure for the prevention of anxiety for children within the scope of the study. This neurogame demonstrates how different coping strategies can be conveyed as a therapeutic measure in a child-friendly manner within an application and how the player's internal state can be integrated in order to influence the game environment and atmosphere and thereby achieve a therapeutic effect. The MindWave headset however used in both projects utilizes only one EEG sensor which could lead to inaccurate measurements. No neurogame has currently evaluated the MUSE headband, which might lead to better results.

3 METHODS

The general research method used as a guiding framework follows the user-centered development principles described by Abeele et al. (Abeele et al., 2011). Firstly, a review of related work and current BCI and EEG technologies for a focus group with psychotherapists was prepared to identify requirements and potentials of neurogames. Secondly, a neurogame prototype using the MUSE headband was developed. Thirdly, a gameplay test with healthy children was conducted to evaluate game design of the developed prototype and used technology.

3.1 Requirements Analysis: Focus Group

As part of the preparation for this work, a preliminary semi-structured focus group with psychotherapists working in a clinic (N=3) was carried out to identify needs and potentials for neurogames. In this clinic, children and adolescents between the ages of 6 and 19 are treated with mental illnesses such as anxiety disorders, depression, eating disorders, ADHD and disorders of social behavior. In preparation for the focus group, an initial research was carried out on the use of mindfulness exercises, relaxation procedures as well as attention and concentration training to accompany and support psychotherapy in order to gain a basic understanding. Questions and first ideas concerning the development of a neurogame (for instance interaction, gameplay, learning) with the MUSE headband have been prepared for the focus group as well. Goal of the focus group was the identification of requirements for a neurogame supporting psychotherapy.

3.2 Neurogame Development

Following the findings of the focus group, a neurogame prototype was developed in constant interaction with the psychotherapists (N=3). The different states of the prototype were shown to the therapists remotely. The test subjects were advised to think aloud while watching the game being played live. Within the application, two players control their characters through different levels of a pyramid with the aim of getting to the lowest level to find the Pharaoh's treasure. Each level consists of a dark, randomly generated labyrinth. Level design and scripting was done using the Unity game engine. A script generates a random map using depth-first search for given x and y dimensions and then places a given number of stone tablets, treasures as well as the exit at random positions within the labyrinth. The integration of a labyrinth as a puzzle element was chosen because labyrinth tasks are used as part of therapies for children as a measure to promote concentration. Both players have a special light source, the radius of which is determined by the concentration level of the respective player. For this purpose, the users wear the MUSE headband, which measures the concentration of the users using gamma waves and incorporates them into the game. To include the EEG data in the application, both headsets must be connected to the MUSE Direct application via Bluetooth and the data must be transferred via Open Sound Control (OSC) using ports 7000 and 7001. UDP is used as the transport protocol. The data retrieval within the Unity application is realized with the help of the extOSC Unity asset. The higher the concentration level, the larger the radius of the light and the faster the players can move. In order to find their way around the labyrinth, the players have to train to control their concentration and receive direct feedback based on the light. The concentration level is required to increase the light radius. To exit a level, the players have to find and remember symbols that open the door to the next, more difficult level. Every level has a time limit. Players have to proceed carefully through the labyrinth, to find and remember all necessary symbols to open the exit gate. Each level has a time limit to add difficulty. In addition, the game aims to improve social skills and teamwork, as the players have to cooperate in order to advance to the next level. Working together and pursuing a common goal can also have a motivating effect on the players. Here, the users are dependent on the performance of the other. They have to agree on how they want to search through the levels, tell each other when they have found certain objects within the labyrinth and help each other to find the way. According to Wiemeyer et al. (Wiemeyer et al., 2016), a common goal as well as mutual dependency are required for cooperation and teamwork to take place. By taking these aspects into account, players should be encouraged to communicate and cooperate with one another in the context of the serious game. The control of the characters and interaction with objects within the labyrinth is done by controller.

3.3 Technology Acceptance and Game Experience

A total of N=21 healthy children were recruited to participate in the first user test in a high school, including n=13 male and n=8 female subjects. The age of the test participants was 10 or 11 years. Subjects had to play the game cooperatively for about 10 minutes and should think aloud. Afterwards they have been given a questionnaire consisting of 30 items including (1) general game preferences, (2) gameplay and movement controls of the prototype (UTAUT - Unified theory of acceptance and technology use), (3) fun and replayability (GEQ-core - Game experience questionnaire) and the (4) integration of concentration measurement and influences on the gameplay (GEQ-ig and GEQ-sp).

4 FINDINGS

4.1 Focus Group

Therapists (N=3) confirmed the need for digital applications to support the therapy of children and adolescents against the background of the large number of young patients and showed a largely positive attitude towards the use of digital media as a therapy-accompanying measure. They stated that exercises to promote mindfulness, relaxation, attention or concentration are often used as part of a therapy and suggested that a therapy-accompanying serious game could aim to promote one of these states of consciousness. The results of the focus group were divided into three therapeutic and learning objectives that a serious game supporting psychotherapy has to offer: (1) Training of attention and concentration skills, (2) Promotion of social and team skills and (3) Distraction from counterproductive thoughts and support for psychotherapy.

1. Training of attention and concentration skills: The digital game has to be designed to train the players' attention and concentration skills in order to teach children with a lack of concentration or attention deficit, to control their concentration in a targeted manner and to maintain their attention over a longer period of time. It should also help them to get into a concentrated state (n=2). Furthermore, the memory skills of the players can be promoted in this context (n=1). The digital prototype is also intended to motivate users to deal with the increasingly complex tasks within the game over a certain period of time and thereby improve problem-solving skills (n=1).

2. Promotion of social and team skills: Since children and adolescents with an attention disorder often lack social relationships due to the symptoms of their disorder and therefore have poor social skills and, in some cases, suffer from social exclusion (n=3). The digital prototype has to improve social skills and teamwork among users promote to improve their social behavior and meet social needs. Two subjects (n=2) suggested to add a multiplayer mode in which player can play together cooperatively (n=2) and competitively (n=1).

3. Distraction from counterproductive thoughts and support for psychotherapy: The game is also intended to distract users from counterproductive thoughts, praise them for successfully completing the levels and thereby give them a sense of achievement, since children with ADHD often cannot complete tasks successfully and suffer from emotional problems (n=2). Furthermore, the digital application should support the psychotherapy of the children and motivate them to deal with therapeutic content, as well as to carry out therapy-supporting exercises on their own responsibility (n=2).

4.2 Prototype Gameplay Test

The gameplay questionnaire consisted of items in the following categories: (1) general game preferences, (2) gameplay and movement control of the prototype, (3) fun and replayability, and (4) integration of concentration measurement and influences on the gameplay. The test took place in the regular school environment of the subjects.

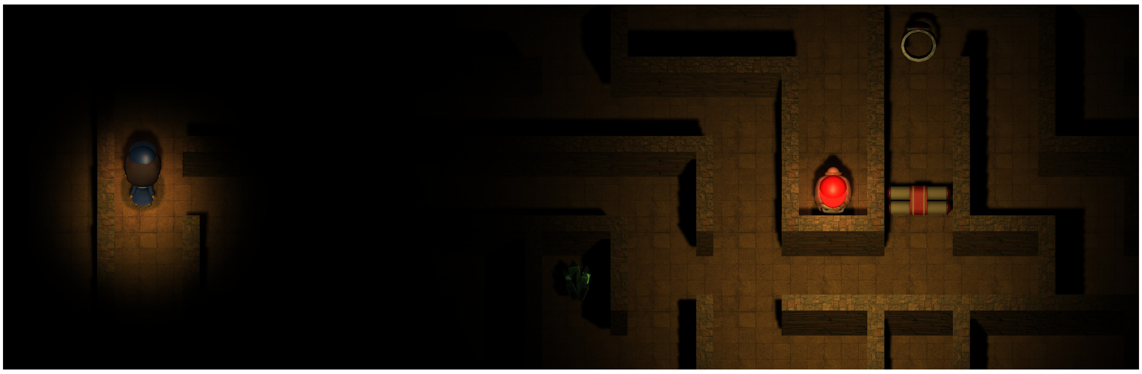

Figure 1: Players must navigate through a dark labyrinth to find the exit to the next level. Depending on the concentration of the player, areas surrounding the player are better illuminated.

4.2.1 General Game Preferences

It was found that the male participants (n=9) play video games more often on average than the female participants (n=3). Each of the male respondents said they played a video game before. The majority of them play one or more times a week (n=8). The majority of female respondents, on the other hand, play video games less frequently, n=2 of the female participants stated that they never played video games before. The subjects cited spending time, fun and entertainment as well as the opportunity to play with others as motivations for playing. Approx. 81% of those surveyed also stated that they preferred to play together with others rather than alone. As part of the evaluation, the data of the male and female subjects as well as the experienced and inexperienced players were compared. All subjects who stated that they used video games at least once a week were classified as experienced players. Subjects who rarely or never play video games were classified as inexperienced players.

4.2.2 Gameplay and Movement Controls

All subjects stated in the questionnaire that they understood the rules of the game quickly and well. 90% of the children also said that they mostly or always knew what to do. It showed that especially subjects who play video games more often always knew what to do. This can be attributed to the fact that these subjects are already familiar with various game principles and mechanics. Within the questionnaire, all of the respondents also stated that they found nothing in the rules of the game to be confusing. The control of the characters and interaction by controller was rated by all children as pleasant and easy as well as quick to learn. Even players who said they had never used a controller could quickly learn how to use it. The majority of respondents also believed that no improvement in control was necessary. However, some of the children said they preferred a narrower or a PlayStation controller.

4.2.3 Fun and Replayability

As part of the questionnaire, n=18 stated that they liked the topic of the Egyptian treasure hunt very much. All study participants also stated that they enjoyed the game and would like to try again. When asked what was the most fun and what they liked best, n=8 answered with ”everything”, n=6 of the respondents stated that they liked the search for objects most within the labyrinth. During the performance of the game tests, it was also observed that the subjects were very happy when they found a stone tablet or a treasure. Furthermore, n=4 stated that they found the inclusion of concentration particularly good in the game. Other favorite game aspects of the children were memorizing the symbols, completing the levels within a given time, playing together and communicating with a teammate, the tension, uncertainty and darkness, the graphics as well as the leaderboard as feedback on their own performance. It was also observed that the players were strongly motivated by the score and the desire to score more points than another team.

4.2.4 Integration of Concentration via the EEG

Within the questionnaire, the subjects were asked to rate the comfort of the MUSE-EEG. The average of those questioned stated that the EEG was “rather comfortable”. The experienced players rated the comfort of the device on average as somewhat more pleasant than the inexperienced players. This could be due to the fact that experienced players are used to using different devices when playing video games and therefore have greater technology acceptance or are better able to put themselves in the game and thereby hide the EEG. However, the game tests showed that in some cases the EEG was too large for the children's head and therefore did not sit well or even slip. 86% of the children stated that they were able to concentrate mostly to very well while playing. It turned out that the female test subjects were able to concentrate better than the male ones in the questionnaire. The female test participants indicated on average that they were able to concentrate very well while playing. The male participants were able to concentrate "mostly well" on average. This could be due to girls' penchant for riddle and puzzle games as well as their innate abilities that give them an edge in such games. However, there is the question of whether it is a false self-assessment or whether the female participants were actually able to concentrate better. This cannot be checked on the basis of the recorded EEG data either, since the recordings cannot be assigned to the questionnaires.

5 DISCUSSION

The results show unique possibilities for designing neurogames to support psychotherapy. The majority of the children appeared very concentrated and immersed in the game while the game tests were being carried out. It could be observed that the players looked very carefully in the labyrinth and rarely overlooked objects. In addition, the concentration level of the test subjects was never permanently low. Individual players were even able to maintain a consistently high concentration. Some children were also very proud when they were able to reach a high level of concentration and communicated this to their teammate. The children judged the targeted control of the light by the concentration in very different ways. Two subjects found this to be difficult to very difficult, n=9 players rated the targeted control as simple to very easy and n=10 children said "it works". Although the female participants reported that they were able to concentrate better than the male participants, the evaluation of the targeted control of light through concentration showed no difference between female and male test subjects. Instead, control by concentration was judged by the experienced players on average to be easier than by the inexperienced. This could be attributed to the fact that the inexperienced players also rated the game difficulty as more difficult and that various actions in the game were more difficult due to their less experience with game principles and mechanics. However, a negative assessment of the targeted control of the light by the concentration can also be related to the fact that in some cases the EEG slipped during the game or received no or only insufficient data for a short time, which represented a low concentration level in the game. The average of the respondents nevertheless stated that the control of the light by the concentration was perceived as "rather not frustrating" and also in the long term as "rather not exhausting". The female participants rated the permanent concentration as less strenuous than the male participants and also stated that they felt less frustration. This could be due to a different frustration tolerance of the female and male subjects or related to the fact that the female players felt they could concentrate better. The children were also asked within the questionnaire whether they felt more concentrated after playing than before. Here, n=18 of the respondents stated that they had been more concentrated after playing. There were no differences between male and female as well as experienced and inexperienced players. Over the course of the game tests, it was also observed that some children behaved loudly and restlessly before playing, but appeared calm, concentrated and immersed in the game during play. To analyze the concentration curve of the test subjects, the gamma value shares of the players were saved during the game sessions. An increased gamma value indicates better concentration. It was found that the gamma waves of the children were individually very differently pronounced.

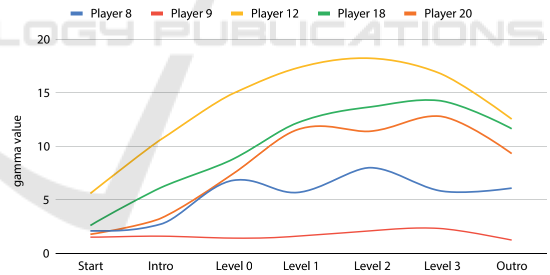

Figure 2: Progression of the gamma value during the game sessions by various players.

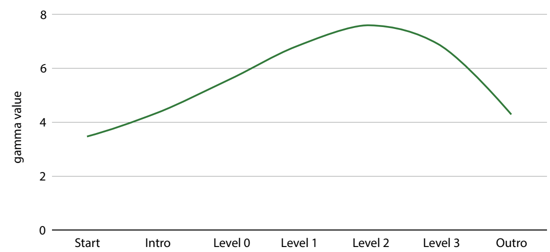

Figure 3: Average progression of the gamma value over all players.

The average gamma value increase of the child with the lowest values was approx. 1.7%, that of the child with the highest values was 13.7%. It was also shown that the test subjects' values fluctuated during play. Overall, the gamma value percentage of all players increased during the course of the game session compared to the start of the game, indicating that all children were able to increase their concentration. However, this increase was different for each individual. Figure 2 shows a comparison of the gamma values of five different players during the game sessions. For the average of the subjects, the gamma value proportion increased continuously from the start of the application up to level 2, where the values reached their peak. Here the gamma values were on average more than twice as high as at the beginning of the game test, so the average of the children was most concentrated in level 2. In level 3 as well as in the outro, the gamma value decreases again on average. The course of the average gamma value share of the subjects is shown in figure 3.

While testing the game some problems with MUSE were discovered. Due to the variation in head sizes, a few subjects had problems tracking their EEG data. The MUSE headband did not always fit the head of a test person well. In addition, there were some disconnections of the MUSE headband during the gameplay tests, so the test subjects had to start from the beginning.

6 CONCLUSION AND FUTURE WORK

Through the implementation and evaluation of a prototypical serious game, it is possible to show that a playful, digital application offers the potential to support the psychotherapeutic treatment of children and adolescents by motivating the users to independently carry out exercises accompanying therapy. In addition, it was shown that the inclusion of measuring neurofeedback in this context can help to support exercises in a self-effective way. Player are able to understand what concentration is all about and how this can support therapy. As part of the evaluation, a sufficiently large number of children were interviewed to receive extensive feedback and clear results regarding the prototype developed. Male and female test subjects with different gaming experience and preferences could be interviewed in order to capture the opinion of different groups of people. Here, however, the number of female participants was significantly lower than the number of male participants. In addition, there were only two subjects who had no experience with video games and three test participants who stated that they used video games on a daily basis. In the context of the evaluation, it would have been interesting to test a higher number of subjects with no or extensive gaming experience in order to better compare these groups of people with one another and to be able to make generally valid statements about these groups. In addition, subjects aged 10 or 11 only were tested, which is why no statements can be made about children in a different audience age. The goals of the digital prototype were to train the players' ability to pay attention and concentrate, to promote social and team skills as well as to distract from counterproductive thoughts and support psychotherapy. As part of the user tests carried out, it was observed that subjects who were initially restless and excited became calmer during the session and concentrated on the game. In addition, the recording of the gamma values showed that the concentration of each subject increased during the game, albeit to different degrees. In order to be able to make further statements about the course of concentration of the users while playing, it would make sense to measure the brain activity of the test subjects while performing other activities and then to compare them with the brain activity while playing the prototype. Some children found it difficult to concentrate and to control their concentration in a targeted manner. Here the players need more individual support from the digital mentor, for example through exercises or techniques to increase concentration, which are taught during the game. The tests also showed that the gamma values of the test participants were very different. It is therefore important that the game is based on the individual concentration values of the users and not on general values. As part of the game tests, the prototype showed the potential to promote the social skills and competences of the children by playing together. Here it could be observed that some children were calm and reserved at the beginning of the game, but increasingly communicated with each other during the game and helped each other to find their way in the labyrinth. All of the children surveyed stated that they enjoyed playing with a teammate and enjoyed the cooperative elements. It also confirmed that children can learn from each other and motivate each other when playing together. Consequently, it makes sense to let children play a serious game together. The prototype is intended to distract players from counterproductive thoughts and motivate them to deal with therapeutic content. All of the subjects stated that they had a lot of fun with the game and wanted to play it repeatedly during the game tests. Various game elements, such as the use of the resources of time and points, contribute to the motivation of the players and the random generation of the labyrinths ensures the replay value. Consequently, a digital serious game offers the potential to support the psychotherapy of children and adolescents and to motivate them to deal with therapeutic content, as well as to carry out therapy-supporting exercises on their own responsibility. The tests carried out also showed that feedback about their performance was important to the children. It was observed that they were motivated by the feedback about their concentration and were proud when they reached a high level of concentration. In addition, the test subjects showed strong interest in the leaderboard, through which they were able to classify their performance. As a result, there were positive effects from the EEG-based feedback on the internal condition of the children. A representation of the concentration curve could also be included in order to give users more detailed and individual feedback. Although different sources show that boys and girls have different game preferences (Kinzie and Joseph, 2008; Scharkow et al., 2015; Procci et al., 2011), the game developed in this work was enjoyed by both male and female testers. It was found here that by combining action and puzzle elements, an application could be developed that appeals to both genders. This confirms the Procci et al. (Procci et al., 2011) that by mixing game elements that correspond to the preferences of boys and girls, a game can be developed that triggers the interests of both genders. It also emerged that the topic of Egyptian treasure hunt and the role of the explorer were welcomed by both boys and girls. As part of the intro, it was observed that the children's ability to read was at different levels and some of the test subjects had problems reading the dialogue. Here it would make sense to speak the text of the mentor to relieve the children and avoid frustration. Animations from the mentor can also be included to make them appear more alive and to increase immersion. Furthermore, the game tests revealed that some of the children found aspects of the application to be too difficult or too easy. This requires an adaptive level of difficulty, which adapts individually to the skills and performance of the children in order to maintain a flow state and to neither bore nor overwhelm the players. The testing of the prototype was carried out with mentally healthy subjects. The next step is to check whether people with a mental disorder still benefit from the positive effects of the game. It is also uncertain how long-lasting the motivation is to play the prototype, and this should be tested in a long-term study.

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