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Timo&Friends: A Diagnostic Tool on the Time Perception of Children with ADHD.

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**Some parts of this report are appropriated from the team report in wich Janneke Peijnenborgh and Pongpanote Gongsook have collaborated. Those parts are clearly marked with footnotes.*

General Summary

ADHD is a common childhood behavioral disorder, which affects the school achievements of children. Children with ADHD typically show some symptoms of time perception problems. Although there are many suggested combinations of ADHD diagnosis approaches, no digital diagnostic tool has been designed ad-hoc to detect the symptoms of time perception problems in ADHD children. A computer game can be a powerful tool to be used in such a diagnosis. In this report a new concept of a diagnostic tool on time perception for children with ADHD will be presented, also the design process of how the high fidelity prototype has been created will be shown.

Management Summary

*Attention Deficit Hyperactivity Disorder (ADHD) has been widely researched in the past decade.
Health professionals do not know exactly what causes this disorder, as it could be genetically or environmentally based [1]. Children with ADHD tend to have abnormal functioning, or dysregulation of neurotransmitters in the brain, such as dopamine [1], and have brain abnormalities in multiple regions. As a result, some researchers have already invented tools targeting the cognitive functions for ADHD diagnosis [10, 16, 17]. Children with ADHD have a reduced functioning of the working memory, which could affect their time perception. They could have difficulties in managing, reading and telling time. Therefore, as an alternative to general cognitive measurements, we would like to explore, if diagnosis of time perception contribute to our understanding of children with ADHD.
Common attitudes of some educators or parents categorize playing a computer game as entertainment, meaningless play and label it is as a waste of time activity [2], underestimating that this attractive activity can provide immediate and formative instruction to players [3].* There are some computer games that have been designed for ADHD diagnosis but they are not focusing on time perception of children. So, in collaboration with KH a videogame as diagnostic tool has been designed focusing on time related topics: executive function, working memory, time estimation, response inhibition, reaction time, and waiting time behavior. The aim of this study is to create a user-friendly non-test like assessment that gives to children the feeling they are playing instead of being tested. Therefore, we are interested to investigate the question whether a computer game on time perception may contribute to a diagnostic process. The system proposed in this report is the first step towards this goal.
This report describes the five phases of the design iteration based on the user centered design approach. These phases include 1) user and contest study, 2) concept development, 3) concept evaluation, 4) final concept development and a further 5) a final evaluation of the interactive prototype. Each of these phases is described in more detail in the follow sections.

** This part of the report is written by Pongpanote Gongsook in the paper in which I am a co-author: A Diagnostic Tool on the Time Perception of Children with ADHD, International Conference on Games and Learning Alliance (GALA 2013).*

1. Attention Deficits Hyperactivity Disorder (ADHD)*

ADHD is a behavior condition identified by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) [4]. The prevalence of ADHD is uncertain. Epidemiological studies have indicated that the general population of the United Stated is affected by this disorder by three to five percent [5], whereas Faraone et al. [6], stated that it affects eight to 12 percent of children worldwide. Studies have shown that the prevalence of ADHD can range from 2.2 to 17.8 percent [7], and around 20 percent of parents of children with ADHD have ADHD themselves [8]. Its symptoms must be present before the age of seven, persist for at least six months, must be poorly adapting and inconsistent with the person's developmental level and severe enough to impact daily functioning across several environment settings [9]. In Neuropsychological studies, children and adults with ADHD reveal subtle but clear impairments in several complex functional systems such as selective attention, memory, reaction time and information processing speed, motor speed and visuomotor ability, inhibitory control, and working memory [10].

There are three subtypes of ADHD: ADHD Predominantly Hyperactive (ADHD-PH), ADHD Predominantly Inattentive (ADHD-PI) and ADHD Combined type (ADHD-C) [5]. Children diagnosed with ADHD-PH are usually overactive, have impulsiveness, and demonstrate excessive moving and excessive talking. Children diagnosed with ADHD-PI are marked by having difficulties with attention skills such as selective attention, and sustained attention. Moreover, they have difficulty organizing tasks, activities, and show increased incidence of learning disabilities but without the hyperactive behavior. Lastly, children who are diagnosed with ADHD-C exhibit mixed behaviors between inattentive and hyperactive [5]

1.1 How to diagnose ADHD*

Despite there being DSM-IV guidelines for diagnosing ADHD, no absolute methods have been defined. ADHD and learning disability are rarely detected until children are four to seven years of age, when they are exposed to reading and other academic tasks [11], and there are clusters of symptoms such as inattention, hyperactivity, and impulsiveness which make the diagnosis process more difficult. Gualtieri and Johnson [10] suggested that health professionals (psychiatrist, psychologist, pediatricians) may diagnose ADHD using a combination of various approaches including but not limited to 1) a medical examination for physical and neurological status, 2) a cognitive assessment of ability and achievement, 3) parents and teacher scores in the Disruptive Behavior Rating Scale (DBRS) [12], 4) the Child Behavior checklist (CBCL) [13], that parents can fill out to describe their children's emotional and behavioral problems, 5) direct observation of the behavior of the child by health professionals, 6) a conventional IQ test, like the Wechsler Intelligence Scale for Children®-Fourth Edition (WISC-IV) [14], to assess for strength and weakness in different kinds of task, and 7) school reports using the Teacher's Report Form (TRF) [15], the Caregiver-Teacher Report Form (C-TRF) [13], or other adjunctive evaluations and questionnaires to help pinpoint specific behaviors.

In addition to those aforementioned approaches, health professionals can use a computer program for assessment such as the Conner's Continuous Performance Test (CPT) [10], which is a test of vigilance or sustained attention, or the Tests of Variables of Attention (TOVA) [10]; moreover, there are some computerized neurocognitive batteries (CNB), including the MicroCOG [16], CogTest (www.cogtest.com), and CNS Vital Signs [17], that have been used to evaluate patients with ADHD.

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1.2 Diagnostic tool on time perception*

Children start to develop their sensitivity for time duration at three years old, and their accuracy in time perception develops with age [18]. Time perception is a conceptual understanding that enables us to predict, anticipate, and respond to events occurring in the environment [19]. With this understanding one can build a concept of time as past or present, and reason about changes and temporal relations of events [20-21]. We require this understanding to organize and plan sequences of actions, particularly our movements, which require an accurate representation of temporal information [22-23].
Children with ADHD have brain abnormalities in some regions such as the pre-frontal cortex, basal ganglia, striatum, corpus callosum, nucleus caudatus, globus pallidus and cerebellum [22,24–26]. Those regions relate to the conceptual understanding of time, and could be the reason why they have difficulties in processing, reading, and telling time [27–29]. In addition, unlike other symptoms that could decline when the child grow up, time perception problems still remain even when the child becomes an adult [30–32]. This makes time perception a suitable factor for diagnosis.

1.3 Working memory on time perception*

From the previous section, we know that there are some approaches for ADHD diagnosis. But none of the aforementioned approaches are designed to focus on the time perception of children.
Therefore in collaboration with the psychologists at Kempenhaeghe, the project has been focused on time related topics: executive function, working memory, time estimation, response inhibition, reaction time, and waiting time behavior. .

- *Executive functions*, which include planning and organization, are affected in children with ADHD (Gau & Chiang, 2013).
- *Working memory* according to (Craeynest, 2010) develops from remembering two targets when the child is 2,5 years, to 3 targets when it is 3 years old and 5 targets when the child is 7 years old.
The working memory in children with ADHD is lower (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005).
- *Time estimation of temporal durations* is deficient in children with ADHD, because these estimations are dependent on working memory (Barkley, Koplowitz, Anderson, & McMurray, 1997). Furthermore, distraction during the presentation of a time interval has been found to decrease the accuracy of children's time reproductions (Zakay, 1992).
- *Response inhibition* One core deficiency in children with ADHD is a deficit that refers to three interrelated processes: 1) inhibition of the initial impulsive response to an event; 2) stopping of an on-going response, which thereby permits a delay in the decision to respond, and 3) the protection of this period of delay and the self-directed responses that occurs within it from disruption by competing events and responses (Barkley, 1997).
- *Reaction time* of the child will be measured because slower and more variable reaction times have been found to be a characteristic of ADHD (Gooch, Snowling, & Hulme, 2012)
- *Waiting time* Impulsive behavior occurs when response produces more immediate, relatively smaller reinforcement at the cost of delayed, larger reinforces (Grey, Healy, Leader, & Hayes, 2009). Extensive research has shown that a key ingredient to reduce impulsive behavior is the ability to allocate attention strategically during the waiting period (Mischel, Shoda, & Rodriguez, 1989).

With qualitative data from observations of a child and quantitative data on his or her performances using the diagnostic tools, a clinician has important information on the time perception of the child, which can be used as part of the psychological assessment and yield better accuracy in diagnosis.

* This part of the report is written by Pongpanote Gongsook and Janneke Peijnenborgh from the team meeting minutes.

1.4 Computer games*

Computer games offer players with intense and often relentless action, immediate rewards, challenges, and appealing stories; these stimuli are seemingly something the brain of children with ADHD eagerly desire, and they are rarely something these children get from the regular world of everyday life outside the digital one [33–34]. Computer games attract children's attention by itself and could stimulate intrinsic motivation for children to play [3]. Computer games could be used as a diagnostic tool, acting as an interactive medium from which a player receives immediate stimulus while playing, while a psychiatrist receives the data of the player's selected actions logged to a database. We cannot say that computer games are definitely more enjoyable than some psychological tests, but we do believe that children will likely choose to play Mario on a Nintendo, rather than to sit and do a psychological test. We aim at creating a user-friendly non-test like assessment. We aim at giving them the feeling that they are playing instead of being tested.

1.5 Related games on the market*

There are some computer games that are designed for ADHD diagnosis. IntegNeuro [35], an objective assessment of cognitive strengths and weaknesses, developed by Brain Resource and the University of Sydney, claim that it could pinpoint young people with ADHD through the tests, which detect variations in sustained attention, impulsivity, inhibition, intrusions and response variability. Groundskeeper [36–37] is a cognitive game on Sifteo Cubes (small, hand-held cube computers) with elements that exercise skills affected by ADHD. It is developed by CogCubed and the University of Minnesota, state that it has accurately predicted ADHD cases between 75-78 percent. Some computer games are integrated with biofeedback but are used as a training tool instead of a diagnostic tool. Examples are Play Attention [38], and S.M.A.R.T. BrainGames [39]. These games are designed to let children control the action on the screen with their brain waves. However, those computer games focus on the general cognitive measures of the brain instead of time perception; therefore, we are trying to find whether the computer game on time perception can contribute to a diagnostic process of ADHD.

1.6 Project requirements

Considering the information on ADHD and the limitations of the related computer games already on the market, we started to develop a videogame as a serious diagnostic tool for children with ADHD symptoms that focuses on time perception. In collaboration with the psychologists at Kempenhaeghe, as mentioned already, for the project it was decided to work on**:** executive function, working memory, time estimation, response inhibition, reaction time and waiting time behavior.
Therefore, the purpose of this study is to design a system that enables psychologist to collect enough data from these aspects to help them in diagnosing the ADHD. Moreover the aim is to create a user-friendly non-test like assessment that gives to children the feeling they are playing instead of being tested. The system proposed in this report is the first step towards this goal. In the next sessions the design process will be explained step by step.

** This part of the report is written by Pongpanote Gongsook in the paper in which I am a coauthor: A Diagnostic Tool on the Time Perception of Children with ADHD, International Conference on Games and Learning Alliance (GALA 2013).*

2 Design iteration and Results

2.1 Development project cycles

Based on the theoretical background, a computer game has been proposed, which addresses the needs and issues of a diagnostic tool for children with ADHD symptoms. The development of the diagnostic tool is mainly divided into five phases based on the user centered design approach (40)
These phases include 1) user and contest study, 2) concept development, 3) concept evaluation, 4) final concept development and a further 5) a final concept evaluation was done. Fig.1 showed the project iteration and each of these phases is described in more detail in the following sections.

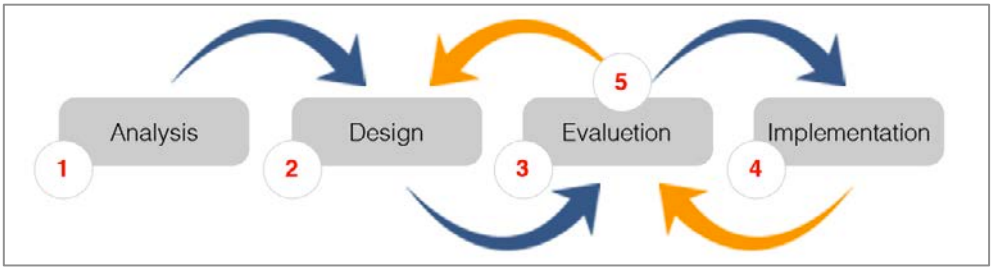

Fig. 1. Diagnostic tool development cycles

2.2 User and context Study

The design process started with a user study (observation and interviews) to get familiar with the context at the Kempenhaeghe hospital and to identify the current needs for children and psychologists.
The first step consisted of an observation study in the Kempenhaeghe clinic with children and health professionals. This study was essential to understand which methods are currently used to diagnose ADHD at Kempenhaeghe. Additionally, two interviews were conducted with mothers (appendix A) to have a better understanding of the daily routine of children in the family environment. The focus was to find out what children (between 4-7 years old) do during the day and which videogames they like. The data from interview and observation were used to create personas (appendix B) for a complete overview of the users. Four personas, two females and two males were created to sort out the differences between children with ADHD and children without ADHD. From the previous exploration/study, interesting points were taken as inspiration for the storyline of the video game to develop. The main points of the video game concept are generated from a regular daily routine of children (4-8 year old) because it makes the game have ecological validity such as: dressing up, preparing breakfast, going to school, coming back home, playing games, eating dinner and the bed routine. These activities are familiar to the children and give us the possibility to eventually expand the game into a training program based on a real life situation. Also, some fantasy environment has been added to the videogame story, to make it more attractive and suitable for the target user group.

3 Concept development

After the user study and the theoretical background the team created some ideas to find the solutions to the main time perception points defined previously with the health specialists.
To find solutions to these needs, a brainstorming session was conducted between the team members. Some solutions were generated for each time perception purpose and examined by the multi-disciplinary team. A first draft of the videogame story was created. The visualization of the environment, tasks and avatars were delineated. The following sections explain step by step how ideas of the story, the avatars and the island have been generated and implemented to the video game.

3.1 The Story

The first step was to create a story frame for the game. Several videogame and toyshops were visited to explore what is on the market. The most up-to-date videogame's styles, stories and interaction suitable for children between four and seven years old were examined. As a result, a mood board (appendix C) and a mind-map (fig. 2) were created to generate ideas during the brainstorm.

The story was created. *Timo is an avatar that comes from a really far away planet that is reachable only by a special time machine (a rocket). The rocket runs out of fuel (stars) during an earth trip, so Timo and his friend luckily land on an island. Timo knows how to refill the rocket but he needs help from the child (user) to find the five stars necessary to go back home. The five starts are scattered around the island and are collected one by one after the child completes a task. The adventure starts from the child's home and it continues outside, where exotic animals, a magic land, a river and funny avatars will try to distract the child (user) in order to test the child's abilities. After the rocket is refilled Timo and his friends are able to go back home and reward the kid with a pleasant surprise.*

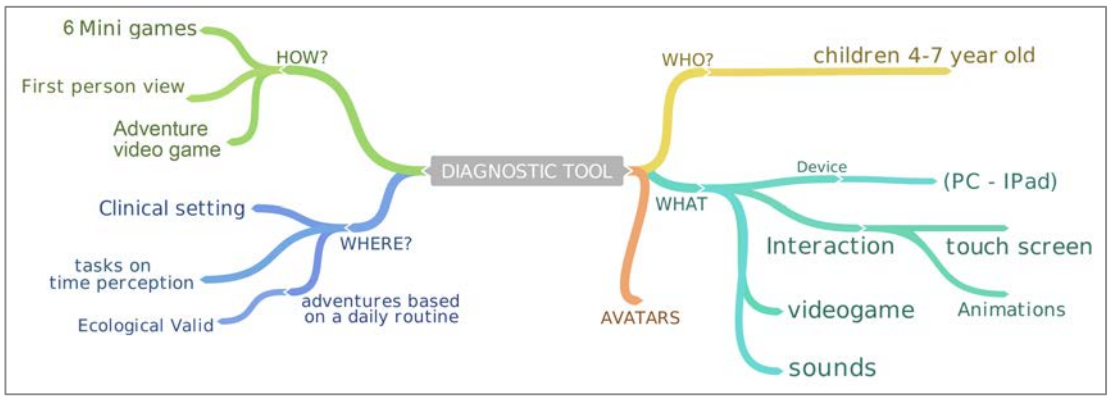

Fig. 2. Mind map

3.2 Timo and friends

After the story was defined, the team met for another brainstorming session focusing on the characteristics and look of the avatars (Timo&Friends). Timo is the avatar that will guide the child during the adventure and the friends are the distractors that try to shift the user's attention during the tasks.

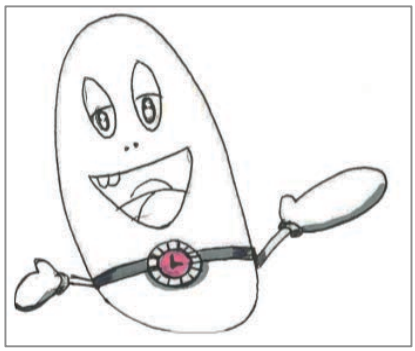

Fig. 3. First sketch of Timo

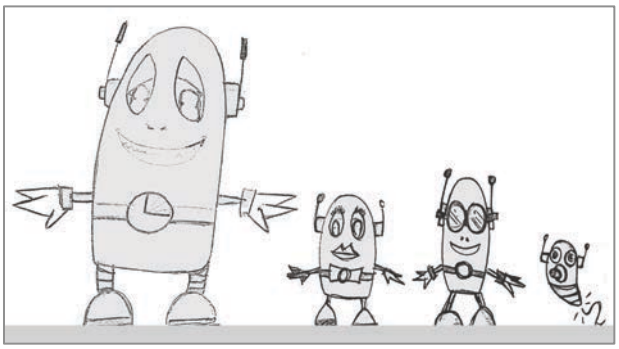

Fig. 4. Idea generation of Timo&Friends

The distractors (friends) are proposed because Kempenhaeghe wants to measure, which external stimulus and to what extend it would distract the attention of the child and how long it takes for the child to refocus on the task. Furthermore, distraction during the presentation of a time interval has been found to decrease the accuracy of children's time reproductions (Zakay, 1992). So to succeed on this requirement each friend of Timo is designed with special features to be significant for the test. "The Fly" is designed as a visual distractor because it can fly around the scene without emitting sound. "The Girl" is designed as an audio distractor; she will emit sound during the videogame tasks. She will also cause a little visual interference (90% sound and 10% visual) to assist the identification of the avatar in the scene. "The Nerd" is the avatar that produces both sound (50%) and visual (50%) distractions. According to the psychologists at Kempenhaeghe, distractors could be best displayed in the following sequence: first the visual, secondly the sound and finally the mix (fig. 5) and they would appear in an variable interval *x* seconds between each other during the entire task.

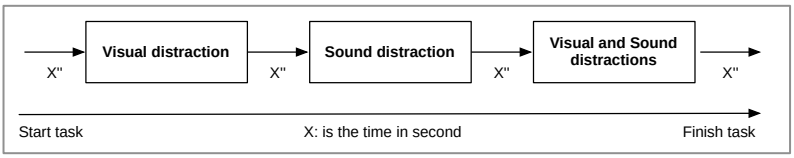

Fig.5. Distraction sequence scheme

Regarding the design of the avatar, Timo was generated and improved during the design process (fig. 3). Consequently the friends were designed in correlation with Timo's style (fig.4).
Moreover, some children were asked to collaborate in a participatory design session to create Timo and friends. Children used a baseline (fig.6) to sketch their ideal avatars (fig.7). This session served as an inspiration for further ideas and especially to adapt the avatars more to the appearance the children like, since they are the target group of this project.

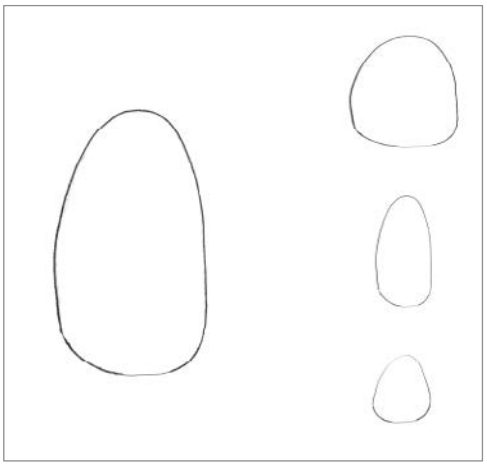

Fig. 6. Baseline for the participatory design

Fig. 7. Some children sketches

The result of the participatory design session shows that children like avatars with arms and legs, funny facial expressions and colorful and round shapes. We also found that female and male avatar must be considered because children drew both genders during the participatory design session. From the team ideas and children sketches the final Timo&friends (fig. 8) avatars were designed, keeping in mind the feasibility of 3D models and animations to implement it into the interactive videogame.

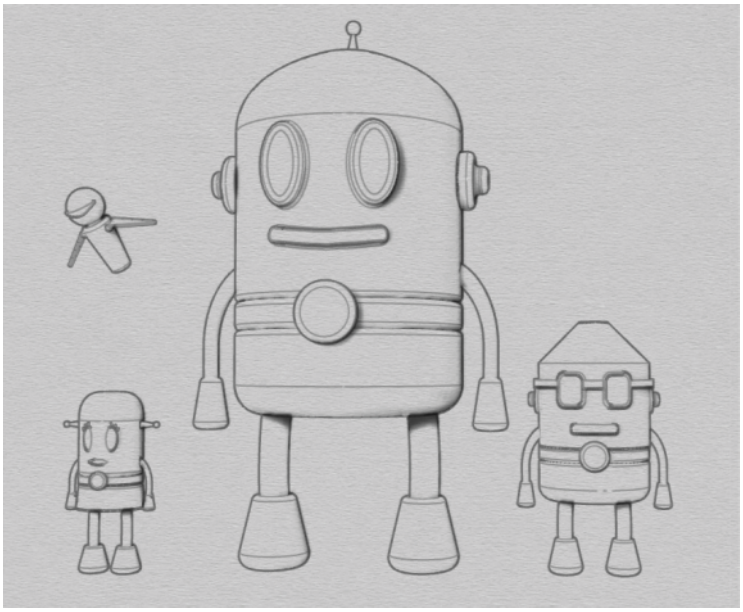

Fig 8. Timo and friends

3.3 The Island

An island was created as the setting for the videogame's tasks. The final design of the island was aiming at a playful environment that children would want to play with. Also, the design takes into consideration that it has to be attractive like the videogames on the market that children are used to playing with. Fig.10 shows the first sketch of the island with all ten mini games generated during the first brainstorm session. Mini games are the scenes of the tasks designed that constituted the complete video game. Ideas for the mini games were sorted and analyzed by the team and as a result we decided to focus on six mini games according on time related topics (session 1.3). The mini games are further explained in the next section.

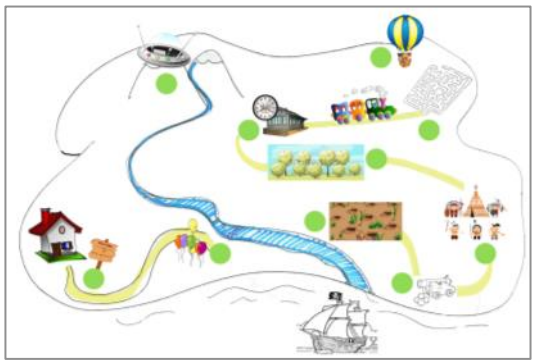

Fig.9. First sketch of the island with ten tasks.

Fig.10. 3D draft of the island with seven tasks.

3.4 The mini games

The project goal is to generate a videogame as an ADHD diagnostic tool, several solutions were generated for the mini games. Some ideas, even though they fitted the requirements, were removed because of the 3D model limitation or because the action of the task represent violence on animals or the environment. The team decided to categorize the diagnostic tool as a 3D single player adventure game because the player assumes the role of a protagonist. The view for the videogame is a first person perspective (1PP). This choice is based on an experiment, where participants who performed tasks in a virtual environment in 1PP had better memory for important tasks and task-related elements, and had committed fewer errors, and exhibited less help-seeking behavior than participants who performed the tasks in a third person perspective (3PP) [41]. Moreover, people who see the virtual world in 1PP could directly link what they see to their own mental states [42]. The videogames is designed for a touchscreen device because it will give more freedom of behaviors and increase the interaction (HCI) instead of a mouse and keyboard.

From the context study and project requirements (session 1.6) six mini-games were rapidly visualized: 1) *Dressing up* (executive function), 2) *Making sandwiches* (working memory), 3) *Cross the river* (Time estimation), 4) *The monkey* (response inhibition), 5) *Magic land* (reaction time) and 6) *The Train station* (Waiting time behavior). Figure 11, shows an overview of the first draft of six mini-games scene. The drafts were helpful to communicate idea to the team and to stimulate discussions.

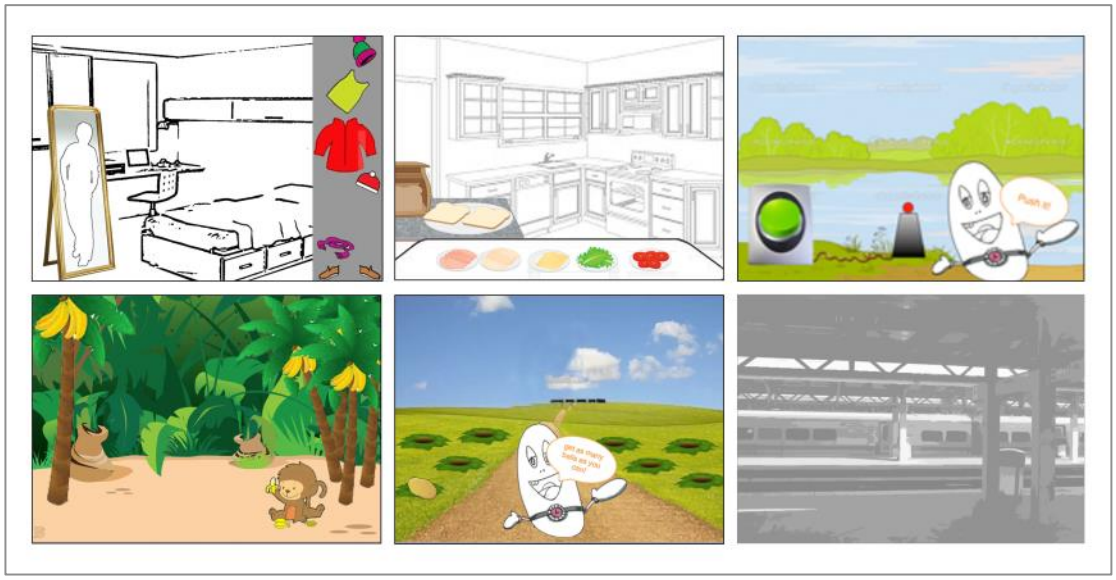

Fig.11. Overview of the draft scenes of the videogame

The team accepted the overall idea of mini-games with some remarks to improve the visualization and interaction of the tasks. The following session describes the mini-games and how the initially abstract ideas became more concrete, and that the tasks functionality are adequate to be used as an ADHD diagnostic tool.

1) *Dressing up*
In this game, the child needs to select clothes and drag them to an avatar as shown in the mirror.
The order in which the child selects clothes will be measured, to see whether the child is capable of planning its actions in the right order. Executive functions, which include planning and organization, are affected in children with ADHD (Gau & Chiang, 2013).

2) *Making sandwiches*
Before the child and Timo can go on an adventure, they need to make a sandwich. In this game, Timo shows the child pictures of the ingredients he wants on his sandwich. Then the pictures disappear, and the child needs to remember which pictures she/he just saw. This task measures the capacity of the working memory.

3) *Blowing a balloon*
When the child and Timo are on their way to the rocket, they have to cross a river. To do this, the child needs to press a button of the remote controller to inflate a balloon. When the child presses the botton too long, the balloon will fly away, and when the child presses it too short, the balloon is not strong enough to take the child across the river. Therefore, the child has to estimate how long 10 seconds last Child has to inflate three balloons to be able to cross the river and to continue the game.

4) *Monkey*
In this mini game, a monkey is throwing banana peels on the road. To cross the road, the child needs to swipe the banana peels and clean the road. However, this is only possible when the monkey is not looking. The monkey is playing hide and seek and appears suddenly. Therefore, the child needs to look for the monkey, and when the monkey disappears, the child can swipe the banana peels. In this game, the response inhibition is measured: can the child wait for the monkey to disappear, or does it act too fast?

5) *Magic land*
The child needs to cross the magic land. In this land, there are magic holes wherefrom suddenly stars will shoot upwards. The child needs to collect the stars by pressing them on the screen.
The shooting of the stars is associated with a sound, but sometimes there will be a sound without the occurrence of a star to test if the child reacts correctly. The reaction time of the child will be measured. Slower and more variable reaction times have been found to be a characteristic of ADHD (Gooch, Snowling, & Hulme, 2012).

6) *Train station*
At this stage of development the scene of this mini-game was not yet definitive, because it was not clear which kind of environment could be more appropriate for the children. The team decided to set the scene in a Train station environment where usually children are supposed to wait for a train.
In this game, the waiting behavior of the child is measured. The child has two options: 1) a small reward, immediately, without waiting; or 2) a bigger reward after the child has been waiting for a period of time.

Once the story was finalized and the six mini-games designed, the team started to improve the visualization and interaction of each task. A low fidelity prototype was created for the user testing.
At this stage of the design iteration, the concept became more concrete, and 3D models were added to the videogame scenes.

4 Concept Evaluations

The first evaluation of the concept was done with a low fidelity prototype. Children without ADHD and experts with backgrounds in clinical child neuropsychology, entertainment computing, human-computer interaction, and user-systems interaction, evaluated the game. Experts can comment on usability issues while users (children) can point out problems related to tasks (Lazar, 2001).

4.1 Low fidelity prototype

A paper prototype of the whole concept was made (fig 12) to obtain users with feedback and to give the children the space to share their own ideas. The first concept evaluation focused on valuating if the content and visualizations are clear and easy to understand, if there is a good flow between the scenes and if it's intuitive. The paper test gave us subjective data from the children and showed how they could interact with the interface. The scenes of the videogame were printed in A3 format with colors.
The test with in-patients of Kempenhaeghe was not possible to conduct without the approval from De Medisch Ethische Toetsingcommissie (METC). So to save time for the project the test was conducted with children (without ADHD) in their family house. The test took 30 minutes for each child.

Fig. 12. Some photos of the paper test with children

The user test was done with five children: two boys of six and seven year old and three girls of four, six and seven year old. All children spoke fluently the Dutch, Italian and English language but three interviews were conducted in Italian and two in the English. Children spoke three languages because their parents have different nationalities and spoken three languages at home.

During the evaluation the participants were provided with tasks, consisting of:
1) Evaluation for Timo and friends avatars and the island (look and feel option).
2) Making a choice for the gender and the selection of the camera (Visualizing option).
3) "*Dressing up"* and "*Making sandwiches"* tasks (Visualizing and interaction options).
4) Getting information on what to expect about the mini-games *"cross the river", "monkey banana"* and the "*Magic land"* (What to expect and visualizing option).
6) Create a scene for the "*Train station"* mini-game (participatory design).
7) "Closing" the videogame (rewards option).

The five tasks of the concept (dressing up, making sandwich, cross the river, the monkey and the magic land) were tested. Also, feedback was received for the home page, profile features and Timo and friends look and feel. The waiting time mini game at this stage was not tested because it was not clearly visualized. The participants were free to ask questions if something was not clear. During the evaluation the interviewer did not disturb the participants unless they were stuck on one task for too long. Upon completion of each task, the participants were interviewed. All the participants received a voucher of ten Euro for their participation to use at the Bijenkorf. The mothers of each child signed a consent form before the test started.

Additionally four specialists in the field of design, IT, psychology, and computer games were selected for an expert evaluation of the first paper prototype. All experts are User System Interaction students and have worked with children in the past. Their expertise was helpful to validate the tasks flow and to improve some technical details of the videogame. The thinking aloud method was used for the expert evaluation, which took 30 minutes for participant. The feedback results are explained in the next session.

4.2 Feedback from expert and children.

This section presents the feedback received from the children during the user test and from the experts from the expert evaluation. Feedback is discussed together because it shows some differences in understanding the tasks. The pictures printed for the test are screenshots of the videogame and are showed in the same sequence to all the participants. The first image showed was Timo and friends (fig.13) which both children and adults really like it because of the look of the avatars.

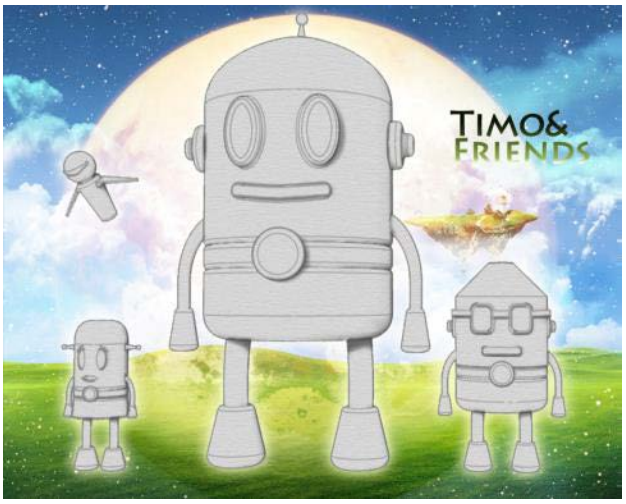

Fig.13. The first picture of user test shown

The second picture shown was the outline of the gender selection (fig 14). This page was designed because we want to tailor part of the videogame for either boys or girls. For example, in the *"Dressing up"* task, the clothes and part of the bedroom change depending of the user's gender.
In conclusion the selection for the gender task was easy to perform and gave the user the impression to start the videogame.

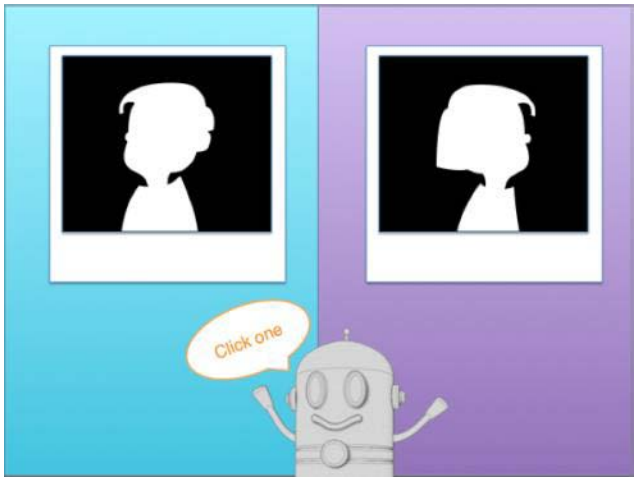

Fig.14. Timo and friends, first pic of user test showed

The next layout was the *"making photo"* task (fig.15) where users easily recognized the camera icon and they could easily relate it with the task at hand. . But some users did not comprehend why it was there and the relation with the videogame. Experts assumed it was for creating the user profile before starting the game.

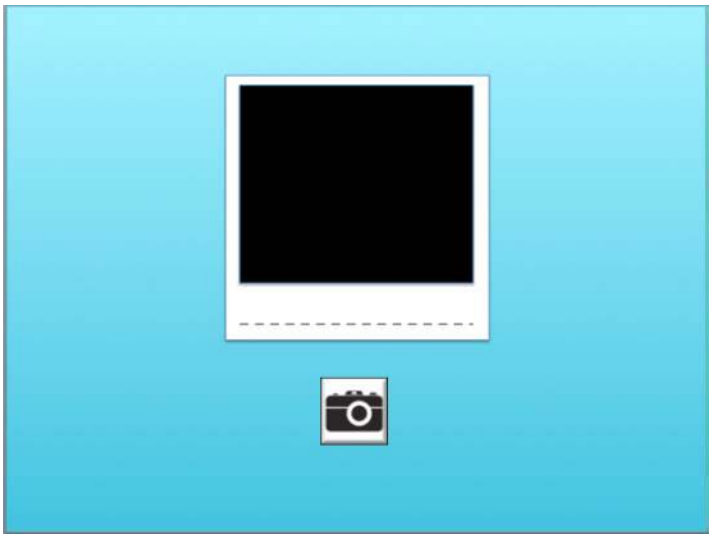

Fig.15. Making photo task

Afterwards, the picture shown was the welcome page where the map of the island (fig.17) is presented. The feedback received showed that the graphics and the icons of the mini games must be improved because it was not clear what the tasks were.

Fig. 16. Welcome page and map with tasks

The user test continued with the evaluation of the *"Dressing up"* scene (fig. 17 and 18). All the participants liked the scene at first sight. The clothes were easily found in the room, even though the majority said the environment is dark and the colors in the room could be improved.
Experts say the room is a mess but children say that is a bit empty related to their real bedroom.
All participants selected each item with a pen (fig.12) and drew a line to the mirror in the order they usually dress up at home. The common order was: T-shirt, pants, pullover, socks and shoes.
Most of the participants, both adults and children, choose the blue pants, because they argue possible stains would be less visible is case of accidents during the adventure.

Participants easily recognized the three avatars in the scene but it was difficult to identify which one was Timo because they have the same colors. Therefore, colors will be added to the avatars for the final user test session. Moreover, all participants saw the stars and the timer in the scene and they understood their meaning.

Fig. 17. Dressing up scene for male users

Fig.18. Dressing up scene for female users

Participants understood the "*Making sandwiches*" task (fig.19) and recognized the avatars placed in the kitchen. Participants anticipated the relation with the previous mini-game and they argued that making the sandwich is part of the preparation for the adventure outside. The only remark was from the adults, who did not recognize immediately which ingredients were placed on the plates.
Children easily recognized the ham, tomatoes, cheese, salami and cucumbers (from left to right).
During the test was observed that the bread should be nearer to the user and the setting of the plates must be improved as well the food texture for a better visualization and interaction.

Figure 19. Making the sandwich mini game

During the evaluation of the scene *"Cross the river"* (fig.20) participants immediately noticed the broken bridge and understood that the main goal of the task was to cross the river but they did not know what to do at first glance. Participates did not understand what the machine does but they assumed the connection with the remote control was part of the task. Some participants thought the machine was a catapult or a robot able to repair the bridge. So the team agreed the design of machine and the remote control must be improved for a better understanding of the task. Moreover, the majority of the participants asked where the avatars were and why they were not in the scene. These remarks were taken in consideration for the next implementation of the scene.

Fig. 20. Cross the river mini game

The fourth scene evaluated was *"The monkey"* mini game (fig.21). Children liked the monkey and they understood it was preventing them to go forward. However, the connection between the monkey and the bananas remained unclear. Some of children thought they had to avoid the bananas peels because the ground was slippery, which would make them fall down and lose the game. Some considered throwing bananas at the monkey so it would go away and they could continue the game. Participants also stated that the scene was dark because of the strong shadows in the setting.

Fig. 21. The monkey mini game

The evaluation of the paper prototype continued with the *"Magic land"* mini game (fig.22). This task had received positive feedback from all participants and they understood something would jump out of the holes and that they had to catch it.

Fig. 22. Magic land mini game

After the evaluation of the five scenes, the participants were asked about how they would like the game to finish. A draft of the sixth scene (fig 23) was created to help the participants to create some ideas of their own. The scenario of the task was settled in a train station environment as it was established during the early brainstorming session. But little insight was found relating to the task so the team decided to find another solution for the *"Train station"* mini game that is explained in section 5.1.

Fig. 23. The draft of Waiting time mini game

4.3 Results evaluation

The outcomes from the evaluation and the overall positive feedback confirmed that all participants liked the videogame and the avatars. As some participants said the scenes were too dark, the team took these comments into account in order to improve the visualization of the videogame, though bearing in mind that this feedback was partly caused by the quality of the printed images.
Indeed, once played on a touchscreen the videogame should be much brighter and more colorful. Some animation and sound effects should also be added to the scene to clarify some tasks and improve the interaction of the videogame.
For diagnostic purposes it was decided that the whole videogame would be implemented in a linear manner so test results could be compared between all children. Moreover, the whole game would need to last between 15 and 30 minutes, but not longer than 45 minutes. The team does not have any supporting data on this matter, as this is the first attempt at a diagnostic tool on this topic. However, psychologists at Kempenhaeghe agreed from experience that a duration above 45 minutes would be too difficult and tiring for the children. Additionally, we decided the possibility for children to choose their gender for the game would remain, but the "making photo" feature would be removed for the diagnostic tool, though it could be developed in a future treatment ADHD tool. The task of "*Train station*" must be at the end, because otherwise the game would no longer be interesting for the children because has to wait for two minutes to accomplish the task. Based on the feedback the team improved the videogame and all components, resulting in an interactive prototype for the next user test with children.

5 High fidelity prototype

5.1 Implementations

After the paper test the team started to improve the videogame based on the feedback received from the children and the experts. This section describes the main improvements of the videogame and how it became the high fidelity prototype. The interactive prototype was created for the usability test at Kempenhaeghe hospital. First upgrading was the graphic of the icons for the map (fig. 24) and also colors were added to the avatars (fig.25).

Fig 24. New icons for the map

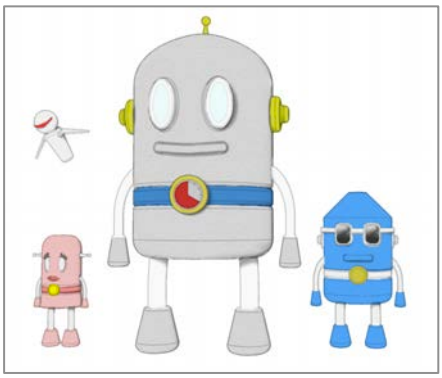

Fig 25. Timo and friends with colors

For the *"Dressing up"* game some improvements were done. The clothes selected come towards the child and are displayed on the avatar in the mirror. This will let the child know that the clothes now belong to the child and do not just disappear. The rest of the scene is similar to the one used in the paper prototype (fig. 17 and 18). Another important progress was done for the *"Train station"* mini game. This mini game scene is settled in the mountain where the rocket is situated (fig. 26), instead of a train station as planned before (paragraph 3.4). The following explanation describes the new solution for this task.

A rocket has been chosen because the results of the first evaluation show that children associated the UFO to aliens and not to robots. In this scene the user has to wait to get a reward and to complete the videogame. This mini game has been renamed to *"Refueling the rocket"* and is based on the theory explained previously (section 1.3). Timo tells the child to wait until the rocket is done refueling.
The child does not know how long he or she needs to wait, however the child does know that he or she will get either a small reward if the screen is touched immediately (go back home with a teleportation) or a big reward if child waits for two minutes (go back home on the rocket and make a tour over the island).

During the two minutes an animation shows the friends refueling the rocket with stars collected previously. This animation is proposed as visual feedback because if nothing is happening on the screen, the child might think the game has failed or is over and will turn towards the psychologist.
Timo emphasizes that the child must not touch the screen but Timo also explains to the child that he can bring him/her home by simply touching the screen if he or she is tired. When the rocket is done refueling, it will make some sounds as a feedback as indication of the end of waiting time task.

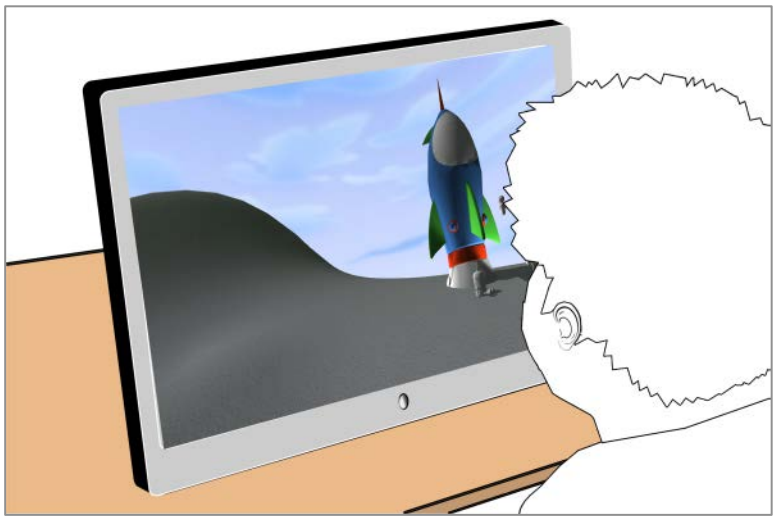

Fig 26. “Refueling the Rocket” is the new scene of the waiting time task

5.2 Prototype Evaluation

For the first evaluation of the interactive prototype a qualitative method was used to explore and evaluate the video game. Six Dutch children without ADHD symptoms (three male and three female) between the age of four and seven were selected but just five joined at the pilot test.
Each participant received a reward at the end of the evaluation. The reward was a mail sent by the team in correspondence of Timo to inform the child that Timo&Friends are back home thank to their help. Inside the mail was enclosed a photo of Timo&Friends and a model of Timo done in MDF cut with laser (fig. 27)

Fig 27. Reward for the user test

The test was set up at Kempenhaeghe and it was in Dutch, so just Janneke, a psychologist and a member of the project team, was in the room with the participant. The duration of the test is set to 30 minutes per session so the child will not get too tired. The diagnostic tool prototype has a controlled

linear story to set a standard play flow for all children. So every child who plays our diagnostic tool will receive the same order of the tasks. This has been designed to reduce the possibility of different experiences. To avoid external interference during the test, two cameras (fig 28) where placed into the room to record the experiment. The videos tapes allowed the rest of team members to observe and furthermore to discuss the performances of children. For the test, the map of the island, choose gender screen and all the mini games were implemented but without the transition between them. The transitions are part of the video game where the child is not playing actively but just observing the animated itinerary between the mini games. Those features are important because the health professionals could observe how child acts during a no-action phase. Cause of lack time this features could not be implemented to the prototype for the user test but the transitions will be added to the final prototype. Timo and friends where not colored and animated because of the time pressure but 80% of the high fidelity prototype was tried as part of the final videogame. This test aims to improve the usability, to give participants real tasks to accomplish, to enable the team to observe and record the actions of the participants and to analyze the data obtained and make changes accordingly.
The next session describes the feedback received from the children and the outcomes from the observation by the team. In this stage of the implementation, Janneke did the instruction of the tasks but in the final prototype Timo will explain the tasks.

Fig.28. Screenshots of the video from the user test.

5.3 Feedback from the user test

The team watched the videos and started the discussion about the performance of the children.
All children liked the story of the video game, Timo&Friends and to play the mini-games.
Some remarks were found such as the graphic design of the map should be more colorful and clear.
Additionally the map must be designed as a first person perspective instead of a top perspective visualization. The mini-games *"Dressing up", "Making sandwich", "The monkey" and "Magic land*" were easily played and completed. So there were no remarks about the interaction and the scenes of this mini games but just some improvement that will be explain in the session 6.1. Only the mini game *"Cross the river"* was difficult to complete because was hard to estimate ten seconds to inflate a balloons. Furthermore the animation of Timo and friends will be added in the next phase. Those feedbacks move forward the project progress to the final implementation and next user test.

5.4 Feedback from Experts

Janneke Peijnenborgh and Jos Hendriksen, psychologists at Kempenhaeghe, perceived some advantage of this computer game because it attracts attention and motivates the children to play and to finish the test. Furthermore the computer game could give important and continuous feedback on the child's performance. Psychological assessment tools by computer have not been used often; mostly they are paper and pencil tests. At this moment, health professionals only collect information about different forms of attention and executive functioning. Experts say that the current computer game might be an important tool to gather important data on time perception, which is an important problem in children with ADHD. Moreover, they believe that collecting information in a more entertaining manner will be more suitable for children and it gives a variety between the paper tests.

6. Final Concept

Based on the result of the evaluation outcomes, some enhancements of the designed were added to the high fidelity prototype. At this stage of the process, a scheme of the whole videogame architecture (Appendix D) was created for a complete overview of the project. Moreover the scheme provides the opportunity to identify some problems and to organize better the progress of the videogame.
The following scheme describes the videogame architecture of ideally final prototype.

6.1 New implementations

The principal realization is the animation of Timo&Friends because it will give feedbacks to children when they have a good performance in the mini games. This feedback will encourage the children to continue with the tasks. On the other hand the animation of the friends generates distraction during the task. The response of the child to the distractions gives important information to the psychologist that observes the child's behaviors. This data provides more material to psychologists to diagnostic the ADHD. Therefore, more accurate data are required, so an eye-tracking device is a possible solution to be implemented for the videogame. This device gives statistic data where the child looks at the touchscreen during the distractors' animation and tasks. Some companies have been contacted for information about the compatibility of their eye-tracking devices with our prototype and to test it in an upcoming version. Concerning the visual design of the videogame the first person perspective transitions were implemented between the scenes. These are in-game camera movements that simulate the navigation of a child to the next mini game after he finished one.
Consequently, the map of the island was redesigned according the first person perspective. A 3D model of child's hands were added holding a map (fig. 29). The graphic of the map improved the feedback accordingly. This new style is more suitable for children and is better for visualizing the tasks.

Fig 29. New map

For the *"Dressing up"* mini game (fig.30 and 31) a more accurate 3D model of the boy and girl has been designed. Additionally, distractors were colored and animated in the whole scenes. The visual distractor flies around the scene, the mixed distractor dances after an auditory signal is emitted from the sound distractor.

Fig 30. Dressing up scene for boys.

Fig 31. Dressing Up scene for girls.

In the *"Making sandwiches"* (fig. 32) mini game, a better position is designed for the plates and six items are chosen as ingredients. The *"Crossing the river"* mini game (fig.33) has been updated with a new model of the machine (balloon maker). Additionally, a more accurate feedback of the button's pressure of the remote control was designed. To complete this task, two balloons minimum and four balloons maximum must be done to cross the river. The first balloon is made by Timo to demonstrate how this mini game works. The third balloon is always a successful task because it allows the child to go forward with the videogame. This option is activated automatically by the system in case the child is not able to estimate the ten seconds for inflating a balloon. The psychologists will use this information at the end of the whole videogame to diagnos ADHD. In cross the river there is no clock because here the time estimation of the child is tested. "The monkey" mini game is similar to the previous version tested earlier (fig.21). The scene is brighter and a bin is added to the environment to contain the banana peels swiped by the child. For the *"Magic Land"* (fig. 34) mini game some visual and auditory feedback are added to the popping star before it disappears. In the *"Refueling the rocket"* mini game (fig.35) the animation of refueling the rocket is implemented and the mountain is green because it creates a friendly and relaxed scene for the child who plays the video game.

Fig 32. Making the sandwich

Fig 33. Crossing the river

Fig 34. Magic land

Fig 35. Refueling the Rocket

The 3D models were created with the free software Rhinoceros 5 for Mac and Blender for Windows. Those models have been implemented by the team using a game engine called 'Unity'. This game engine provides a game creator to control and detect all game object's behavior with a programming language named 'C#'. Therefore, it is possible to program an embedded trigger into a specific game object for the detection when this game object has any interaction with it.

We plan to collect quantitative data while they are playing and write the data to a logging file. Those data show what actions have been done and the time stamps of that action. This logged file will later be read and analyzed by a health professional.

7 Conclusions

Since the final concept of the videogame is still being further implemented, the conclusions presented herein are observations for the current state of art in the project. However this high fidelity prototype discussed earlier, is near completion and will be tested at Kempenhaeghe with ADHD children. The purpose of this study is to design a system that enables health professionals to collect enough data to help them in diagnosing ADHD more accurately. The system proposed in this report is the first step towards this goal. There are some methods for ADHD diagnosis but none of the current approaches are designed to focus on the time perception of children. Children with ADHD have a reduced functioning of the working memory, which could affect their time perception. Considering the information on ADHD and the limitations of the related computer games on the market; we designed a videogame as a serious diagnostic tool for children with ADHD symptoms with focus on time perception. We believe that a computer game is good for providing immediate feedback and an attractive story; these are sort of stimuli that the brain of ADHD children yearns for. Therefore it can be a powerful tool to use in diagnosis especially with children with ADHD-symptoms.
During the design iteration, the needs and issues were identified with the user study and addressed during the concept development. A high fidelity prototype is created that contains six mini games to test children on time perception tasks: executive function, working memory, time estimation, response inhibition, reaction time and waiting time behavior. The usability tests show that the normal children without ADHD symptoms very much liked the whole videogame.
The story and Timo&friends received positive feedback from children and experts who participated in the test. They said that Timo gave the impression of the leader and each avatar was properly enacting the role as distractor properly even though they were not animated during the test. The island gave the idea to be a magical and exotic environment and some tasks were even reflecting real life conditions (ecological validity).

The *"Dressing Up"* mini game in which the child needs to select clothes in a proper order, measures the child capability of planning its actions in the right sequence (executive function). This mini game received positive feedback and participants completed it easily. We believe that children with ADHD symptoms could have some problems in completing this task.
The same was for the task *"Making sandwiches"* in which the child needs to make some sandwiches according the ingredients he/she remembers from the pictures briefly showed beforehand (working memory). For the *"Crossing the River"* mini game most participants mentioned that they liked the scene but it was not clear what they needed to do. Participants said this task was the most difficult and they liked it least. We affirm that some changes must be done into the scene and for the time range (currently 10 seconds) to inflate the balloon. This will be tested and definitive during the next user test.
In *"The Monkey"* mini game participants really liked the monkey animation and they successfully completed the task. The child has to swipe the banana peels from the road when the monkey is not looking. In this mini game, the response inhibition is measured by observing the child's ability to wait for the monkey to disappear or if he/she performances too fast. The mini game *"Magic Land"* received positive feedback and no improvements were required because the team and psychologists observed that the task was clearly completed. The final task *"Refueling the rocket"* was not completely implemented during the evaluation test but the team was able to identify important information to continue to improve this mini game. The animation of the final reward was not implemented, but all of the participants really like the idea to have an attractive and happy ending in the videogame.

No conclusion can be drawn on whether the system indeed improves the diagnosis of ADHD because the prototype was not tested with children with ADHD. However, the evaluation results do seem to suggest that the system is aiming in the right direction for achieving this. The system incorporates many features the children and health professionals will want to have. The main advantage of this computer game is that it is a user-friendly test which children like to play because they do not feel like they are tested. Furthermore the computer game may given important qualitative data by observing a child's behavior and quantitative data on his or her performances using the videogame as diagnostic tools. As a result health professionals have important information on the time perception of the child, which can be used as part of the psychological assessment and yield better accuracy in diagnosis. Future research and user test are to further evaluate the video final video game.

8. Future work and recommendation.

The results from the evaluation are from children without ADHD symptoms. This calls for research to see if all of the needs and issues are covered also for children with ADHD. A user test with ADHD children is planned at Kempenhaeghe early next year. Health professionals know from previous experience that before Cristmans's holiday, children are stressed so their performance will be compromised as well the results of the test. The user test will set up as the previous usability test so is possible to valuate the new implementations of the prototype and if there are significant differences on the performance between children with or without ADHD. During this study, the focus was more on children needs as final users of the system. Those needs and requirements were validated with the health professionals. In my opinion for future work, research is required to identify the needs of healthcare professionals because in part they are users of the system. They will interact with the computer game to collect and to analyze data from the system. Even though there are software tools for those tasks, a complete package system will be a good solution for health professionals.

Additional implementation such as the eye tracking device and the software for analyzing the facial expressions will be added to the system. Those devices would provide more information to help health professionals to diagnose the ADHD. Some companies have been contacted for information about the compatibility of their devices with our prototype for further implementation.

The most significant result from the evaluation is that children and health professionals really appreciate the idea and the quality of the outcomes achieved. The prototype will be finish by December 2013 because some features are in progress of implementation such as: animation of the avatars, visual and auditory feedback, Timo's dialogue and the reward feedback at the end of the videogame.

In my opinion, the look and feel of the videogame could be improved in the future. This aspect was not achieved properly because of lack of time and the incompatibility of the 3D rendering software used. As interactive designer with background in product design, I truly believe that the look and feel are an important requirement to consider in a videogame, especially if it is designed for children.

The following picture (fig.36) shows a possible option for the graphic and image resolution of the "Dressing Up" scene. This example could be used for the whole videogame scene and for the interface. It provides a better visualization of the scene and gives to users a better feeling when using the videogame. Additionally, it helps users to identify the items clearly by highlighting areas of importance through use of colors, texture and 3D models placement. An additional point to explore is the timer proposed sand-timer in the previous picture. This solution was originated during the interviews with mothers (appendix A) for the user and context study. They explained that the sand-timer was used for some tasks to motivate the child to finish on time. These suggestions need to be evaluated in a further user test.

Fig 36. A new suggestion for the look and feel of the videogame

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Appendix A: Daily routine interviews

Mother 1
Giovanni, male 7 years old without ADHD symptoms.
Character: a bit shy, curious, observer.
Hobbies: hockey and drum.
Like: Animals, nature, Lego, Risk, army, cars and Wii
Tablet: Angry birds, Sonic jump, Bubble balls, Contre jour http://chillingo.com/games/contre-jour/

7:15 Parents weak up Giovanni. Mom prepares the breakfast while Giovanni goes to the toilet and play with toys.
7:35 Breakfast for around 20 minutes. Is forbidden to play during breakfast even though Giovanni insists to do so.
7:50 Giovanni goes to brush teeth and to dress up. He uses an hourglass of 3min to brush teeth while the mother prepares the clothes on the bed. Giovanni dress by himself. Mother suggested that different sizes of hourglass (10, 5, 2 minutes) could be used for different tasks.
8:15 Go to school by bike or car if the weather is not good.
8:30 At school. Giovanni has a Montessori education and he is the group 3.
14:30 Back at home. Giovanni plays till 4 pm. He plays with Lego, toys and board game. No video game. If the weather is good they go to the park.
16:00 Giovanni prepares the sandwich under the supervision of the mother.
17 – 18:30 Option A: Sport activity two days a week. Option B: If Giovanni does not have sport he continues to play. Sometime he gets bored and he involves the mother in the game to find new alternative game.
18:30 Giovanni plays again. Only on Sunday morning he can watch a movie or cartoon on TV.

19:00 The mother prepares the dinner and sometime Giovanni helps her for the dinner or he plays with his toys.
20:00- 20:30 Giovanni goes to bed. One of the parents usually the father reads a fable to him. Or they invented a story with the Pantomime game from the company Haba.

Mother 2

Giuseppe, male 6 years old with ADHD symptom	**Emma, female 4 years old without ADHD symptom**
Character: active and intelligent	Character: predominant and she wants conquer the world.
Hobbies: soccer	Hobbies: hockey and drum
Like: Lego, cars and board game	Like: Animals, nature, Lego, Risk, army, cars and Wii
Tablet: angry birds	Tablet: Angry birds

7:30 Parents woke up the kids who go to bathroom. They help each other for the toilet.
7:45 Breakfast ready (10/15min)
8:10 Kids dress really fast themselves so they can play 10/20 min.(no tablet) before go to school.
8:35 Go to school
15:15 Kids are back at home. Often they bring a friend or they go to the house of friends for the "Afspreken". During this time they play with board game, Lego or in the garden if the weather is good.
16:00 Snack break
17:00 Option A: Giuseppe goes to soccer tree time a week and Emma to Swimming. They prepare everything them self.
Option B: children continue to play but sometime they involve parents to play with them or to create new games and toys. Sometime they help mom to cook and prepare the table for dinner.
18:30 Back home if the did sport.
19:00 Dinner
20:00 Go to wear the pyjama
20:30 Read with dad comics/fables. In around 10/15 min they are sleeping.

Appendix B: Personas

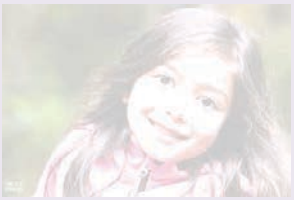
Dirk, (7,2 years old with ADHD symptoms).

Dirk is a child that loves being outdoor. He likes to build huts, play football, or help his father at the farm. He has a lot of energy, is creative, funny and always enthusiastic about trying new things. Because he is so enthusiastic, he sometimes doesn't think enough and forgets to think about possible consequences. Therefore, he often has a lot of little accidents, but this doesn't hold him back a next time. Parents report that Dirk always was a child that didn't need a lot of sleep. It was difficult to get him to sleep when he was little. Still, he does not fall asleep early and he is pretty early awake in the morning.
Dirk has problems remembering what to do. Every morning mother has to guide him while getting on his clothes, because Dirk forgets what to do or is distracted by other, more interesting stuff. Furthermore, Dirk is a child that likes to talk a lot. During mealtime, parents have to stop him otherwise he forgets to eat. While playing, Dirk can't stay with one activity: he switches a lot between what he does. At home this isn't a big problem, because there is lots to do at the farm. However, at school this is a big problem. Dirk has trouble staying at his seat, he wants to walk a lot and uses excuses to get out of his seat. This is disturbing his classmates. Also, Dirk has difficulty waiting until the teacher tells him he can talk. Often, in his enthusiasm, he shouts answers through the class. The teacher has to grumble a lot. Furthermore, Dirk has difficulty in remembering the learned stuff. This has a negative impact on reading and mathematics. However, Dirk has average cognitive capacities, so this can't be the reason for his learning difficulties. Dirk doesn't like to go to school, he is happy when stay at home.

Thomas (6,8 years old)

Thomas is in groep 3 (first grade). He likes going to school, he has some nice friends and he likes that he finally learns to read. Mathematics however is more difficult for him, but with hard work he manages. His favourite thing at school is drawing or gymnastics.
He lives at home with his mom and dad, and a younger brother (4;3). Although he likes to play with his brother, they sometimes argue. In his free time he plays with his brother, has play dates with friends. It is no problem for him to keep himself busy. He has a lot of interests and can play for hours. He likes building with Lego, and makes complete cities with Lego. Furthermore, Thomas is a member of the local judo club. Parents are proud of the fact that he is self-reliant. He can make his own sandwich in the morning. They don't have any big concerns about Thomas.

Emma (6,11 years old)



Emma is a six year old girl, living in a city with her parents and an older brother (Lucas, 10;2). She is a sweet girl, never getting into big problems. She has a few nice friends, with whom she has play dates. She likes to play role play like mum and dad, or school. She wants to be a teacher when she is older. Her favourite colour is pink and gold. When she is alone, she likes to draw or play with Barbie dolls. At school, she has a nice teacher, her grades are above the average.

Natalie (5;4 years old with ADHD symptoms)

Natalie lives with her mother during the weeks, and in the weekends she lives with her dad. Her parents divorced two years ago. It can be difficult for her to adjust after a switch from houses, although parents are on speaking terms and try to make it as easy as possible. Natalie likes to dance. She is fond of music and has ballet training once a week. Although she likes this, it is difficult for her to remember what the steps of the dancing routines are. At school, the teacher mentions that she can be very dreamy. Often Natalie does not hear it when the teacher calls her name, because she is dreaming. Although she is a smart girl, she often forgets to keep on working. She starts enthusiastically with her assignments, but after a few minutes she stops and just looks outside. Therefore, she often is not finished with her assignments when the other children are finished. This makes her insecure, although she is smart enough.

Appendix C: Videogames moodboard for idea generation

Appendix D: Final architecture of the videogame