A First Step Towards Assistive Technology for Adults with AD(H)D

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ABSTRACT
Many people with AD(H)D (Attention Deficit (Hyperactivity) Disorder) have problems performing at school, at work and in social life. The combination of having problems with planning and concentrating often result in time management problems. This paper investigates whether a robot coach can help people with AD(H)D to better concentrate on a task by giving reminders and compliments during a task. To this end, experiments have been conducted with subjects and the gathered information has been analyzed. It was found that further study is required in order to get reliable results. However, it seems that the first step towards such a system with a robot coach is perceived mostly positive, even though many adjustments still have to be made. This paper is a contribution to a seemingly new area in the assistive technology world, by introducing new ideas, using technology, in order to help people with AD(H)D and maybe others.

Keywords
AD(H)D, assistive technology, adults, robot coach, compliments, reminders, verbal, nonverbal.

1. INTRODUCTION
ADHD is a well-known childhood disorder, which affects about 3-5% of the children in primary school. The three core symptoms of ADHD are attention deficit, hyperactivity and impulsivity. Part of the attention deficit is the fact that these children are easily distracted/bored, have trouble finishing tasks, have trouble reading, planning and organizing. Besides being easily distracted, it is also possible that someone with ADHD gets over focused on a task; also known as hyper focus. This mostly appears to happen whenever a person with ADHD is interested in his/her activity [18, 28].

Within the diagnoses of ADHD there are three subtypes, namely the inattentive one (also known as ADD), the Hyperactive-impulsive one and the combined one. People with ADD show symptoms of inattention, whereas the Hyperactive-impulsive subtype mainly shows symptoms of hyperactivity and impulsivity. The combined type has all three of the symptoms [17].

Since research showed that the core symptoms of AD(H)D are still present in adulthood in about 30%-60% of the cases [18], AD(H)D in adults has gotten more attention [1].

With the upcoming interest in ADHD, various researches have discussed several topics like the efficiency of Neurofeedback versus Pharmacological Support [11] and the effects of Biofeedback [8, 9]. Also research into the effect of different treatments (cognitive, behavioral and pharmaceutical) has been conducted [20]. Most of the (research into) assistive technologies focus on organizing tasks, planning and time-management [29, 27]. Shih also conducted research on the effects of controlled environmental stimulation on limb hyperactive behavior [25]. However, besides a couple of applications available in the Google Play Store and the App Store, (research into) assistive technology to actively help people with ADHD during tasks is not easy to find yet. This raises the question whether or not such technology is desirable or not. And if it is desired, how can such technology be effective?

1.1 Problem statement and research questions
Even though ADHD is a common disorder in our society, there seem not to be many helpful applications specifically meant for people suffering from this disorder. Many people with ADHD have problems at school, work and in social life. The combination of having problems with planning and problems with concentrating can obviously result in time management problems for people with ADHD.

Based on the mentioned support and assistive technology for people with ADHD, which seems to focus mostly on organizing tasks, planning and time management, the question rises whether this kind of support helps people who have to complete tasks for which a longer period of concentration is desired. If a person takes longer than planned on a task, the planning no longer works. One reason someone may take longer on a task is because he gets distracted during it.

In this research the following questions will be evaluated:

RQ1: How do adults with AD(H)D experience a robot coach, which supports them by giving reminders and compliments to help them stay concentrated while performing a task?

- Do the subjects find the prototype useful? (RQ1.1)
- How do the subjects experience the embodiment? (RQ1.2)
- What do the subjects feel about the position of the robot? (RQ1.3)
RQ2: How are the different sorts of messages, provided by the robot coach, experienced?
- Do the subjects prefer verbal (spoken) messages versus nonverbal (visual and sound based) messages? (RQ2.1)
- Do the compliments given while a subject is concentrated motivate to continue to stay concentrated? (RQ2.2)

RQ3: Are the messages given by the system, while the subjects are concentrated, perceived as a distraction?

In order to find answers to the research questions, an experiment with subjects diagnosed with AD(H)D will be conducted. For this experiment a prototype, which gives subjects reminders and compliments based on their levels of concentration, will be developed and tested. Based on the responses of the subjects an attempt will be made to answer the research questions.

The rest of the paper is structured as follows. In Section 2, literature background to this study is provided. In Section 3, the hypotheses of this study are stated. In Section 4, the methods used in this study and the approach taken will be discussed. In Section 5, the results will be presented. These results will be discussed in Section 6. In Section 7, the limitations of this study will be discussed and in Section 8 ideas for future work will be presented. In Section 9 the conclusion is given.

2. BACKGROUND

2.1 Assistive technology

Zuckerman et al. [30] designed an assistive technology (TangiPlan) to enhance executive functioning (impulse control, emotional control, flexible thinking, working memory, self-monitoring, planning and prioritizing, task initiation and organization [22])1 among children with ADHD. They mention that even though several assistive technologies were presented to enhance executive functioning, none of these were specifically aimed for children with ADHD. The technology, which they developed in a later study [30], was found to be helpful for with children diagnosed with ADHD. They found that the experiences of the subjects towards TangiPlan were positive. Even though this technology assists people with ADHD, it is not aimed to improve the users concentration.

As mentioned before, Shih [25] studied the effect a controlled environmental stimulation on limb hyperactive behavior and found that this was helpful to actively reduce limb hyperactive behavior. In a baseline phase he monitored the amount of limb movement and found a critical value for movement for the participants. In an intervention phase the participants were given a favorite stimulation as long as their limb movement did not exceed the critical value from the baseline phase. Both participants were able to reduce their limb movement and the results were significant.

However, none of these studies looked into the effects of assistive technology to increase the attention span of someone with ADHD.

Also, there are some applications available in the App Store and the Google Play Store that help with organizing tasks, time management, training the brain to be able to concentrate longer and keep focused on a task2. Some of these are especially developed for people with ADHD and some are not.

From the reviewed applications, only two were developed to help people to stay focused on a task [24, 4]. From these two only one is specifically meant for people with ADHD. StayOnTask PLUS [24] uses a randomized timer to check up on the users with customizable alarm tones, so they can check whether they are still focused on the task they were performing. ADD/ADHD: Keeping on Track [4] allows the user to set (verbal) reminders and notifications to be played or spoken on a chosen time-interval until an end time is reached. Thus, both are timers which are used to remind people to stay focused on their task. However, none of these applications know whether or not the user is distracted and whether or not it is experienced as helpful.

This leads to research question one: How do adults with AD(H)D experience a robot coach, which supports them by giving reminders and compliments to help them stay concentrated while performing a task?

2.2 Embodiment

Bainbridge et al. [3] studied the effects of the presence of a physical robot. This study indicates that it is more likely that people will follow the commands from a physically present robot than from a video of the same robot. This research also notes that the amount of respect people afford to a robot increases when a physical-present robot is used. Another study (Lezyberg et al. [19]) indicates that physical embodiment helps to improve the learning in robot tutor interactions.

Fong et al. [14] describe that the form of a robot may constrain the human’s ability to interact with the robot, meaning that if a robot consists of parts that are not intuitively touchable, that humans may feel constrained to touch it.

2.3 Interruptions

The research of Gillie et all [15] found that neither the length of an interruption or the point at which the task is interrupted are important in determining whether or not an interruption is disruptive. They found that the nature of the interruption in terms of similarity to the continuing task and the complexity in terms of the amount of processing or memory storage required, however, seem to determine how disruptive interruptions are.

In this research the compliments can be seen as interruptions to the subjects. This leads to research question three: Are the messages given by the system, while the subjects are concentrated, perceived a distraction?

2.4 Messages

2.4.1 Compliments and feedback

Mumm et al. [23] found that whenever an interface does not provide users with feedback on their performance, that the intrinsic motivation is likely to be lower than in a situation where users do receive feedback on their performance. Furthermore, they found that praise as well social comparison helped increase motivation with the users. However, Bracken et al. [5] mentioned that praise also may be self-defeating as users might feel that they’re thought to be stupid and that this is the reason they receive the praise. This leads to the question whether or not the compliments given by the system are perceived as motivating.

1 Opinions are distributed about whether or not attention is included in the summation of executive functions. However, in this paper we’ll assume that it is not.

2 In total eight applications were considered relevant for this topic. The search terms were “ADHD” and “focus” in both the Google Play Store and the App Store. The date of search was 14 October.
2.4.2 Pitch and contours of sound
According to W. Chase [7] the effects of a low pitch are associated with negative emotions, such as fear, seriousness, anger, etc. Also it is noted that the effects of a high pitch are usually associated with positive emotions, such as happiness, excitement, triumph etc. Furthermore, Fisher et al. [13] found that rising contours in sounds make people feel more at ease than falling contours.

2.4.3 Color
In color psychology a lot of research has been done into the effects of color on people’s behavior. Elliot et al. [12] describe that color effects are context specific. They also describe that of the existing research that is theoretically based, most has been loosely guided by Goldstein’s proposal that red and yellow are naturally experienced as stimulating and disagreeable, and that green and blue are experienced as quieting and agreeable. Red and yellow focus people on the outward environment and they produce forceful, expansive behavior. On the opposite, green and blue focus people inward and produce reserved, stable behavior.

The theories mentioned Section 2.3 and 2.4 lead to research question two.

3. HYPOTHESIS
In this section the hypothesis will be stated, based on the previously discussed literature.

3.1 Hypothesis to RQ1
It is expected that the subjects in this experiment will perceive the system as positive and will find it useful (RQ1.1). This hypothesis is based on the positive findings with TangiPlan and the technology to reduce limb control. Please note that these systems have different purposes than the system proposed in this study.

As for the embodiment (RQ 1.2), it is expected that the subjects will not necessarily find the embodiment pleasant, but not unpleasant either. However, that it will help them to keep better focused on their task.

The robot will be placed diagonally in front of the subjects in order to let it be not as confronting as it would be when it is placed right in front of them, but still noticeable. Therefore it is expected that the position of the robot will support the feeling of them being watched, but further will not have any additional effects (RQ1.3).

3.2 Hypothesis to RQ2
Based on the research of Gilie et al. [15] it is expected that the verbal interruptions are more disruptive than the nonverbal interruptions, since a short sound does not require the same amount of memory storage as a sentence. Because of this, it is expected that in the case of the compliments, the subjects will prefer the nonverbal messages and in case of the reminders, it is expected that the subjects will prefer the verbal messages.

Also, based on the findings of Mumm et al. [23], it is expected that the compliments given by the robot coach will increase the subjects’ motivation.

3.3 Hypothesis to RQ3
It is expected that the given compliments compliments will interfere with the concentration of the subjects and therefore will be perceived as distracting. However, the amount of distraction is expected to be larger with the verbal compliments than with the nonverbal compliments.

4. METHOD AND APPROACH
In this section the methods, which are used in this research are discussed. These are the methods of data collection as well as data analyses.

4.1 Methodology
To answer the research questions, a within-subjects design will be used. In the experiment, subjects are asked to perform a reading task during which a robot coach will support them by giving reminders and compliments based on their levels of concentration.

The experiments with the subjects will be counterbalanced, so some subjects will be presented with the verbal version of the system first, while other subjects will be presented with the nonverbal version of the system first.

After the experiment, the subjects will be interviewed. In this interview questions will be asked, regarding the research questions. The interview will be semi-structured, so it is possible to ask for clarification and to ask follow up questions on answers the subjects give, with the purpose of the interview in mind. Based on the answers of the subjects, an attempt will be made to answer the research questions.

4.2 Data analysis
After the experiment, the subjects will be interviewed in order to gather information about their experiences.

The answers given to the questions during the interview will be categorized. The different categories will be: General, Experience, Usefulness, Design of the robot, Position of the robot and Messages.

In addition to the answers of the interviews, the number of reminders and compliments during the experiments will be noted. A higher number of reminders will imply a higher level of distractions during the test. Furthermore, the time it takes a subject to continue his task after a reminder will be registered.

During the experiment, the behaviors of the subjects will be monitored and noted. This might reveal more information about their experience with the system in combination with their given answers in the interview.

When all the data is gathered and categorized, answers to the research questions will be found by comparing the different answers of each subject, but also by comparing the answers of different subjects. Furthermore, an attempt will be made to find connections between the answers of the interviews and the other gathered data.

4.3 Subjects
For this experiment, the subjects need to be diagnosed with a type of ADHD. They also need to be older than eighteen years. Furthermore, their first language needs to be Dutch in order to be able to read the text.

4.4 Setup
For this experiment a Wizard of Oz setup will be used. The test subjects are seated at a desk or table in their own home environment. They are allowed to have their phones/laptops/tablets et cetera with them while performing the task, since these items are also present in a normal situation.

The robot will be placed diagonally in front of the subjects, so that they are not facing Dot directly. Furthermore, robot will be placed on an elevation under which a Bluetooth speaker is placed, which presents the messages to the subjects.

A camera will be placed right in front of the subjects, looking upwards to their faces, so their eyeballs can be tracked as well as other movements. The camera will be covered as much as
possible in order to let it be less distracting to the subjects. An example of a test setup can be seen in Figure 1.

Figure 1: example setup for a subject

The experiment leader will be in a different room, watching the subjects with a phone, which is connected to a GoPro Hero4 camera, to track the behavior and eye movements of the subjects. Whenever the test subjects are distracted or concentrated for a longer period of time, the experiment leader executes the associated action, which the robot coach performs. A detailed flow-chart diagram can be seen in Figure 2.

In order to determine whether a subject is distracted, the eye-movement and other behaviors will be observed. Whenever someone is reading, the eyeballs shift from left to right and back again for the next sentence. Thus, if this eye-movement is not visible, it can be assumed that the subject is not reading at that moment.

4.5 Procedure

The subjects are invited to participate in the experiment. In advance the subjects are asked to fill in the consent form and a short questionnaire about their age, gender, education, reading frequency and type of ADHD.

Next, the subjects are instructed not to move the camera and the book and are informed about the task and the fact that they will be interrupted for filling in questionnaires.

After this, the experiment leader will leave the room and signal the robot to introduce itself. In both rounds, the robot will introduce itself by saying that it is going to support the subject during the task. Further information is not given in order to prevent the subjects from changing their behavior during the experiment.

After half an hour, the subjects will be interrupted from their first task, which consists of reading a chapter from the book. The subject gets a moment to fill in the questionnaire and then the second round will begin, in which they will read another chapter.

The experiment leader leaves the room again and the robot introduces itself again. After half an hour the subjects will be interrupted for the second time and will be presented with a short questionnaire.

After they have filled in the questionnaire, the interview will take place. When this is finished, the subjects are allowed to ask questions about the research.

4.6 Feedback design

In this section, the reasoning for the design aspects of the robot coach are presented.

4.6.1 Appearance

Based on the theories about physical embodiment, the choice was made to use a physical-present robot.

The robot chosen for this experiment is named Dot (see Figure 3). This robot is designed for children, to learn how to program. The design of the robot is made in such a way, that it is easy to touch. However, a head and an eye are not intuitively touchable elements; this in combination with the impact of physical presence on the amount of respect supports the decision to choose Dot for the experiment.

Furthermore, the size of Dot is not very large, which makes it easy to place on a desk. Besides the fact that the eye is not an intuitively touchable element, it also represents the ability to see, which is an important aspect in this study.

4.6.2 Environment

The test location for this experiment will be the home environment of the subjects, since a possible product in the future will be used in the home environment of the subjects. The setup will be equal for each of the locations as much as
possible, however, due to the different locations, it is possible that there are minor deviations between the different experiments. Since this study investigates the experiences of the test subjects and not the success of the prototype, this is not expected to be a problem.

Also, since the experiments will be conducted in the subjects’ home environment, it is expected that the subjects are able to compare the differences they experience easier with a “normal” situation, since they are familiar with the environment and the accompanying distractions.

### 4.6.3 Messages

As mentioned earlier, the robot coach will present different kind of messages. Since praise seems to affect the intrinsic motivation of a human (see Section 2), the robot will give compliments. These messages occur whenever the subjects have been concentrated for a longer period of time. In addition to these messages, the robot will also give the subjects reminders whenever they get distracted from the task.

The textual messages are presented in Table 1 and 2. In the situation in which the messages are nonverbally presented, the messages consist of a color (coming from the “ears” and the “eye” of dot) as well as a sound. The sound produced by the robot coach to compliment the behavior of the subjects will have a rising contour (see Figure 4) and the sound made when the robot coach wants to attend the subjects on their distraction, will have a falling contour an octave lower (low pitch) than the compliment (high pitch) (see Figure 5).

![Figure 4: compliment](image4.png)

![Figure 5: reminder](image5.png)

In this research, coloring is used as was discussed in Section 2. In the case of the reminder messages, the ears and the eye of Dot will become orange, which is experienced as disagreeable. In the case of compliment, the ears and the eye of Dot become green, which is experienced as agreeable.

<table>
<thead>
<tr>
<th>Table 1: Reminder messages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dutch</strong></td>
</tr>
<tr>
<td>Je lijkt afgeleid, probeer weer aan de slag te gaan.</td>
</tr>
<tr>
<td>Misschien kan je beter weer aan het werk gaan.</td>
</tr>
<tr>
<td>Probeer door te lezen.</td>
</tr>
<tr>
<td>Ik zie dat je afgeleid bent, probeer verder te gaan met je taak.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Compliments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dutch</strong></td>
</tr>
<tr>
<td>Je bent goed aan het werk!</td>
</tr>
<tr>
<td>Ik zie dat je goed aan het werk bent!</td>
</tr>
<tr>
<td>Ga zo door, je bent goed aan het werk.</td>
</tr>
<tr>
<td>Probeer dit vol te houden!</td>
</tr>
<tr>
<td>Ik zie dat je goed aan het werk bent!</td>
</tr>
</tbody>
</table>

### 5. RESULTS

In this section the results of the user evaluation will be presented. This is a summarization of the log data, observations and the interviews.

#### 5.1 Subjects

The subjects were individually asked to participate in this experiment. In total, the experiment was performed with six subjects. However, due to technical difficulties the results of two subjects excluded from this experiment, therefore the number of subjects is 4 (n = 4).

50% of the subjects are female and 50% of the subjects are male. The ages of the different subjects were 23, 24, 31 and 50 (M = 32, SD = 10.84). 75% of the subjects are diagnosed ADD and 25% is diagnosed with ADHD.

Furthermore, 50% of the subjects read longer texts at least once a week and the other 50% read longer texts at least once a day. 50% of the subjects are educated of following education at WO level and the other 50% is educated or following education at MBO4 level (see Table 3).

<table>
<thead>
<tr>
<th>Table 3: an overview of subject information</th>
</tr>
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<tbody>
<tr>
<td><strong>Subject</strong></td>
</tr>
<tr>
<td>Subject 1 (1)</td>
</tr>
<tr>
<td>Subject 2 (3)</td>
</tr>
<tr>
<td>Subject 3 (5)</td>
</tr>
<tr>
<td>Subject 4 (6)</td>
</tr>
</tbody>
</table>

#### 5.2 Log data

Each subject had a different amount of reminders during the different rounds of experiments. In Table 4 an overview is given of the amount of reminders (-) and compliments (+) in the different rounds.

<table>
<thead>
<tr>
<th>Table 4: Number of reminders and compliments</th>
</tr>
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<tbody>
<tr>
<td><strong>Subjects</strong></td>
</tr>
<tr>
<td>Subject 1</td>
</tr>
<tr>
<td>Subject 2</td>
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<tr>
<td>Subject 3</td>
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<tr>
<td>Subject 4</td>
</tr>
</tbody>
</table>
5.3 Observations
In the experiment, the subjects are observed during the task. Interesting behaviors were noted and are presented in this section.

5.3.1 Subject 1
The first subject seemed to be distracted quite often in the beginning of the first round, but after 10 minutes this decreased. In the last few minutes she got distracted, but returned to her task within 10 seconds on her own. In the second round, she ignored her phone beep, which she did not in the first round. Also, whenever she received a reminder, she started to work again within 10 seconds.

5.3.2 Subject 2
The second subject did not seem to look up at the robot coach in both rounds. Since this subject was not distracted once, no reminders were given.

5.3.3 Subject 3
The third subject did not look at the robot in the first (verbal) round when the robot gave a compliment. When the subject got the reminder, he laughed and then continued within 10 seconds. In the second round, the subject looked at the robot with the first compliment and after that ignored the robot. Whenever the lights of the robot dimmed (see Section 7.1), the subject looked at the robot in both rounds.

5.3.4 Subject 4
In the first round, whenever the subject was distracted, she only continued the task if she received a reminder. In the second round, she continued with her task four times on her own, within 10 seconds. In the first round, she looked frustrated at the robot when she received her second compliment. She was working for three minutes at that time. She also ignored the last two reminders of the robot coach. With all the other reminders, she started working within 5 seconds to 56 seconds. In the second round, the subject started working after a reminder within 2 seconds up till 2 minutes. She also received two reminders in the second round to which she reacted irritated. After one reminder she said: “Ah, fuck you”.

When she received the first compliment in the verbal round, she had to laugh. With both compliments, she got distracted within a minute after receiving the compliment.

5.4 Interviews
In this section the responses to the interviews are presented.

5.4.1 General experience
75% of the subjects experienced the text as boring. 25% felt that the content of the text was quite interesting.

All of the subjects felt that the robot coach was really watching them during the task. One subject mentioned that this was due to the fact of knowing that there are cameras pointed at you.

When the subjects were asked about their general experience with the system, one subject mentioned that she was very distracted in the beginning about the question how the system worked. She felt provoked to test what the effect of her behavior would be to the system.

Another subject mentioned that he felt that he did not benefitted from the system in this experiment since he already was well concentrated during the tasks. This was the subject who found the reading text interesting.

Also, two subjects mentioned that they did not realize that there would be a questionnaire about the text, which may have resulted in extra motivation in the second round.

5.4.2 Usefulness
50% of the subjects mentioned that they felt that the presence of the coach made them feel more motivated to continue with their task. One subject mentioned that he did not know whether the robot coach made him feel more motivated, since he also was motivated to do the experiment. Another subject did not feel that the presence of the robot coach made him feel more motivated, since he already was well concentrated.

Regarding the increase of concentration due to the physical presence of the robot coach, 50% of the subjects did not feel that the physical presence of the coach helped them to be more concentrated. The other half did feel that this helped. One of them mentioned that the physical presence of the robot helped him to be more focused towards the assignment. Another subject said that that the presence of the robot coach helped to be less distracted by things in the environment, however she mentioned that she still had moments where she read a part of the text, but did not know what the content of the text was afterwards.

In addition to the increase of concentration due to the physical presence of the robot coach, there also may be an increase of concentration due to the functionality of the system. 50% of the subjects felt that the functionality of the system helped them concentrate better. One of these subjects mentioned that it helped to keep her attention focused towards the book. Another said that it helped, because it corrected him when he was doing something different. One subject felt that due to the messages he received, he got distracted more than he would have without the system. It distracted him in such a way, that he got lost in the text.

75% of the subjects felt that they could execute the task faster with the robot coach. Two of the subjects mentioned that this was due to the fact that they continued more quickly when they were distracted. The other 25% did not feel that the assistance of the robot coach made it possible to execute the task more quickly. This was the subject who thought the text was interesting and did not get any reminders. None of the subjects felt that the robot coach made them execute their task more effectively.

75% of the subjects felt that their productivity in the task increased by using the system, because it reminded them to continue, which made them realize that they were distracted and therefore helped them to finish the task more quickly. The other subject mentioned that in this experiment, his productivity did not increase, since he was already able to concentrate quite well. However, he mentioned that if he had to read something he did not want to, he could imagine that the system would help to increase his productivity, since it prevents the subject from being distracted and doing other things.

None of the subjects felt that the robot made their task easier. Also none of the subjects thought that the system helped them to perform better on the task. One subject mentioned that she still skipped some parts of the text. Another subject mentioned that the robot did not help her to be more focused on understanding the text and that it therefore did not help her to perform better on the task.

75% said that they did not feel that the system would be useful in their daily lives. One subject mentioned that she felt that it limited her in her actions and that this was annoying to her. Another subject said that he felt that the system could be helpful in moments where he needs to be concentrated. He mentioned that he normally prefers to switch between tasks when he is working and felt that the robot might limit him in doing so. One
of the subjects mentioned that she would find it useful and helpful for doing her homework.

50% of the subjects said that they would not use the system if they had the recourses available. The subject, who thought that the system would be useful in her daily live, said that she would probably use it when she had access to the recourses.

Another subject mentioned that even though he would not use it in his daily live, that he might use it in periods when he has to study for exams or when he has to read non-interesting material. One of the subjects, who did not think he would use it, said that this was due to the fact that he did not have to read uninteresting texts and therefore did not have problems concentrating when he had to read.

When the subjects were asked if they thought whether or not the system was useful when people had to finish a reading task, all subjects said that they felt that the system could be useful for people who have trouble concentrating. One subject mentioned that when someone is distracted, the system is able to help realize this. Another subject also mentioned that she thought that the system prevents someone from being distracted by his environment. Yet another subject mentioned that the system could be useful for people who are distracted quickly, but that it might be distracting for people who are already well concentrated.

The subjects answered differently to the question whether or not they would recommend the system to other people. One of the subjects mentioned that he did not know to whom he could recommend the system, but he thought that it could help people who get distracted quite often. Another subject thought it might be helpful to people who are still at school or have to study for tests, since the system can help you to stay concentrated. The last two subjects both mentioned that if adults do not feel like using the system, it is easy for them to “walk away”. Both of them also mentioned that it might be useful for children. One of them said that she thought that it could help children to work better and the other said that it might help children to learn how to work task-oriented.

5.4.3 Design of the robot
In this section, the responses of the subjects about the appearance of the robot will be discussed.

One subject felt intimidated by the big eye of the robot and mentioned that she felt like “big brother is watching”. She also mentioned that she thought that the system would be more effective if you would not be able to see it.

Another subject felt that the appearance of the robot was fine, but that he did not expect the robot to speak because of its appearance. He felt that changes to the robot might help to increase the robots effectiveness, but did not know which changes those should be.

The next subject did not really care about the appearance of the robot and mentioned that he thought it was more important that it functions well. However, he also mentioned that the eye in the robot gave him the feeling that he was being watched and that distracted him several times. He did not feel that any changes to its appearances would increase its effectiveness.

The last subject liked the appearance of the robot. She found it adorable. She mentioned that she did not think that its “cute” appearance is distracting. She said that if the robot would not be appealing to her, she would not want to have it and thus would have been less effective. Afterwards, she mentioned that if she would have met the robot out of the experiment, she would have picked it up to look at it closer.

Finally, the subjects were asked if they thought that it might help if the coach was not physically present. Two of the subjects felt that this might help, since they did not like the feeling of being watched. One of them mentioned that having a virtual coach might prevent someone from being distracted by the feeling that they’re being watched. One of the other subjects mentioned that if the coach would not be physical, the feeling of being watched would decrease. He said that the feeling of being watched helped him to work more focused on his task and therefore preferred a physical robot. The other subject thought that if the system would be presented by a virtual coach on a smartphone she would get more distracted by things on her phone and that it therefore become more distracting.

5.4.4 Position of the robot
Two of the four subjects felt that they would have positioned the robot the same way as in the experiment. This includes putting it on an elevation.

One subject did not feel that the location of the robot was disturbing, but mentioned that when she would use it at home; she would prefer to put it directly on the desk/table.

Another subject felt that the robot was put down pontifical, which provoked her to test its functionality. She mentioned that she would have preferred a situation where the robot was placed out of sight or not existing at all.

5.4.5 Received messages
During this part of the interview, the subjects were questioned about the different type of messages they received (verbal versus nonverbal) and the moments at which they received the messages.

One subject mentioned that he would have liked to know in advance how the system was going to react. Furthermore, it became clear that two of the four subjects understood without any help what the types of nonverbal messages meant. The other two subjects mentioned that they did not understand what the different sounds and lights meant. One of them, however, said that he thought green meant positive and orange negative. The other subject did not understand any of the nonverbal messages.

50% of the subjects preferred the verbal messages. One of them mentioned that she preferred the fact that the voice had a more alarming effect on her and that they were easier to understand. The other subject felt that he had to be more attentive to the nonverbal messages to know what the robot did and therefore preferred the verbal messages.

The other subjects both felt that the verbal messages were more distracting, because they diverted their attention away from the text when they were reading. One of them mentioned the alarming effect of the verbal messages, but for him it had a distracting effect. This was the subject who only received compliments.

When the subjects were asked what they felt about the compliment messages, the subjects answered differently. One subject felt that the verbal compliments were distracting and thus not motivating. However, in case of the nonverbal compliments she thought that they were motivating. Another subject felt that verbal compliments were more distracting than the nonverbal compliments. He said he was able to ignore the nonverbal messages better than the verbal messages. He also mentioned that he thought that the nonverbal compliments were less motivating than the verbal compliments. Yet another subject felt that the compliments helped increase motivation and did not find them distracting. The last subject felt that all
compliments were distracting and would prefer to remove them from system.

75% of the subjects were fine with the timing of the messages. Only one subject said that she found the compliments distracting. She mentioned that when she finally was concentrated, she received a compliment. Another subject suggested increase the number of compliments. The other two subjects felt the number of compliments was fine. They stated that more compliments would have been annoying, but that a decrease of the number of compliments was not necessary either. One of these subjects mentioned that whenever he was about to lose interest in the task, he received a compliment and this helped him to increase his concentration.

One subject mentioned that sometimes when she was not reading but was staring at the book, the system did not notice that she was distracted. Another subject mentioned that sometimes when she was reading that the system gave her a reminder. Another subject also mentioned, she read better during the second (i.e., last) round than she did in the nonverbal round. She felt that the robot coach kept a closer eye on her and was more present.

6. DISCUSSION
In this section the findings of this study will be discussed.

In all cases the number of reminders in the second round of the experiment were equal or less than in the first round. This might indicate that the system helped the subjects to be more concentrated, after they got used to it. Another explanation (which is more probable) could be that the system distracted the subjects more in the first round than it did in the second round and they adjusted better to the situation in the second round.

The results regarding the embodiment of the robot coach imply that the current prototype of the system might have been somewhat distracting. Two subjects specifically mentioned that the presence and/or the appearance of the robot coach did distract them. The other two subjects did not feel the same. However, one of these subjects mentioned that if she had encountered the system for the first time outside an experimental environment, she would have picked up the robot, which might indicate that the embodiment was distracting for this subject as well. Also, during the observations it was noted that the subjects who had trouble concentrating on the task, looked at the robot at least once. In contrast, the subject who was able to concentrate well mentioned that the physical presence of the robot helped to focus better on the task and that the appearance was not distracting. Since the majority of the subjects felt or indicated that the robot coach was distracting to them, it seems that the hypothesis regarding RQ1.2 is not supported.

Regarding the position of the robot, most subjects did not feel that this increased their distraction. This supports a part of research question 1.3. All subjects felt that they were being watched, however, it is not possible to determine whether this is due to the physical presence of the robot, or because of other aspects of the system (e.g. the timing of the messages).

All subjects who had trouble concentrating during the experiment felt that the system helped to execute the task faster. The same was felt about the productivity increase. Also, all of the subjects experienced either an increase in motivation or concentration due to either the physical presence of the robot or the functionality of the system. This might indicate that a system, used in this experiment, could help people with AD(H)D to perform better on tasks that require longer periods of concentration.

When the subjects were asked if they would recommend the system to other people, none of the subjects initially recommended the system for other adults (with ADHD). It was mentioned that the usage of the system by adults is always voluntarily. Therefore, the proposed system will probably not have any effect without an already existing intrinsic motivation or external motivator (e.g. parents or a boss or teachers or having a deadline). All subjects, however, mentioned that the system might be useful to other kinds of people (e.g. children in school, students, people having trouble concentrating).

At this moment, the prototype has not been fully developed which may have influenced the experience of the subjects in a negative manner. The mentioned positive feelings towards the system, however, might indicate that it is possible that people who have trouble concentrating might benefit from a more developed system. This partially supports the expected result for research question 1.1, since the robot coach was not solely perceived as positive and useful.

The subjects preferred different forms (verbal vs. nonverbal) of the messages. It is not possible to draw one conclusion from the data. This might indicate that the preference towards one type of message is personal. Since the gained results on this topic were inconclusive, an answer to research question 2.1 cannot be stated. Further research into the effects of the different types of messages needs to be done in order to make more reliable conclusions. It was noticed, however, that the subject who was able to concentrate completely on his own and thus only received compliments, preferred the nonverbal messages. Also, the subject who had the most trouble concentrating and thus mostly received reminders preferred the verbal messages. Since the purpose of the system was to increase concentration, the results above might indicate that during moments of concentration, the nonverbal messages are less intrusive and therefore less distracting and that whenever a subject has more trouble concentrating, the verbal reminders are more intrusive and thus are more helpful to the subject to snap out of the distraction and return to the performance of the task.

For three of the four subjects the compliments were, in one form or another (the form of messages they preferred), motivating. Only the subject, who was not able to concentrate on his own very well, did not like the compliments. Therefore the hypothesis to research question 3 is partly supported. An explanation for the fact that one subject did not experience the compliments as supportive might be that whenever she received a compliment she was working at most for five minutes at most. This time span might be too short to let a compliment be effective. According to the theory of Brophy [6] about teacher praise: “Infrequent, contingent, specific and credible praise seems more likely to be encouraging (and perhaps reinforcing, although more with respect to general effort than to specific behaviors) than frequent but trivial or inappropriate praise.” Since the compliments given to the mentioned subject were received after at most 5 minutes of concentration, this might have felt as inappropriate and not credible.

This might indicate that there exists a relation between the period of concentration before receiving a compliment and the positive effects of that compliment.

7. LIMITATIONS
Since this research covers many different aspects (the effect of reminders, the effect of the physical presence of a robot on concentration, the effect of verbal versus nonverbal messages), it does not provide as reliable results as would have been when the different aspects would have been studied in separately. In this study it was difficult to determine which element was
responsible for the statements, opinions and perceived distraction of the subjects.

Furthermore, there is limited research so far into assistive technology for aiding people to help concentrate. Therefore, the findings in this study cannot be easily compared to prior studies.

Also, reliability of this study is limited due to the low number of subjects.

The experiment was performed in the home environments of each subject. The different distracting aspects of those environments ma have lead to less reliable data. Therefore, reliable conclusions on the effectiveness of the system cannot be drawn.

Three out of four subjects stated in the interviews that the text they had to read was very boring and stupid to them. This negative emotion towards the task may have influenced their opinion on the system. This also holds for the positive feelings of the other subject towards the system.

Also, since the determining whether or not the subjects were distracted was done by a Wizard, minor errors may have occurred.

At last, the robot that was chosen for this design was originally designed for children, which may have contributed to the distraction of the subjects and/or the degree to which the subjects take the robot coach seriously.

7.1 Technical issues

During the experiments the robot had to be connected via Bluetooth to the program, which was installed on a tablet in order to control the robot. However, every once in a while the robot disconnected from the program, which was running. Therefore the light intensity of the ears fluctuated at those moments. The light intensity lowered and went up again when the program was started again.

Also, due to other technical issues two experiments were excluded from this research. In one of the experiments the connection with the camera (a GoPro Hero4) disconnected in the second round, which resulted in an inability to observe the subject. In the other experiment the connection the Bluetooth turned off whenever it got disconnected. Therefore the experiment leader was forced to walk into the testing environment to turn the Bluetooth speaker on multiple times.

From the results, it became clear that the meaning of the nonverbal messages was not clear all the subjects. This may have influenced the perception of the subjects towards the system.

8. FUTURE WORK AND ADJUSTMENTS

As already mentioned in Section 7, the current research consists of many aspects. In order to be able to design a better system, the effects of the nonverbal versus verbal, compliment, reminders and the presence of a physical robot separately in the context of aiding to concentration should be studied better. Therefore, it would be a suggestion to study effect of reminders on concentration, the effect of a physical present robot on concentration and the effect of verbal or nonverbal messages on concentration separately.

Also, in order to eliminate the human error in determining whether or not someone is distracted, further research can be done into systems that detect distractions automatically. Examples of already existing studies that focus on distractions are the Distraction and drowsiness detection system for computer users, proposed by Wu et al. [29] and the studies into detecting driver drowsiness. For example, the study of Alshaqaqi et al. [2] proposes an algorithm to detect driver drowsiness.

Further improvements to the system could be the ability to determine the frequency of compliments based on the distraction of the user, the ability to personalize the type of messages and a possibility for the users to collect data about his performance.

9. CONCLUSION

We have seen that even though AD(H)D is becoming a more known disorder, there has not been much research into assistive technology for people suffering from this disorder.

This study investigated whether assistive technology for people with AD(H)D can be useful and how people experience working with such a technology. In order to answer this question a prototype was designed and tested. The technology consists of a robot coach that supports people with AD(H)D during a tasks in which concentration is required (in this study, a reading task). The support consists of giving reminders whenever the subjects are distracted and compliments whenever they have been concentrated for a longer period.

The system was evaluated as useful and perceived as positive on some aspects, but also as distracting and negative on other aspects. The current design of the robot was perceived as distracting to some subjects. This may have influenced their feelings negatively towards the functionality of the system. Other subjects did not feel that the embodiment contributed to extra distractions. Most subjects did not feel that the current placement of the robot coach contributed to extra distractions.

The results regarding to the given messages were non conclusive to answer the research questions. Further research needs to be done into the different variables of the messages, which are nonverbal, verbal, reminder and compliments.

Results regarding the motivational (towards concentration) aspect of the compliments might imply that compliments mainly are perceived as motivating, which is in agreement with prior studies on this topic. In this study, there seems to be a relation ship between the time that someone has been concentrated and whether or not the received compliments for that concentration are perceived as positive. It seems that the shorter the subjects has been concentrated, the more distracting (and thus not motivating) a compliment is.

In order to collect more reliable data and to determine if a system like this can be useful to persons with AD(H)D, and maybe others, further research into the different aspects of the system needs to be conducted.

10. REFERENCES


