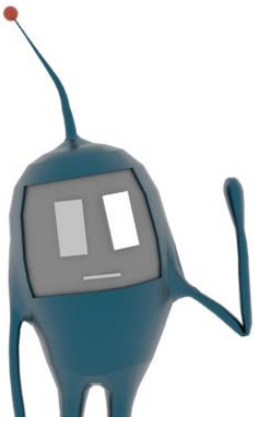
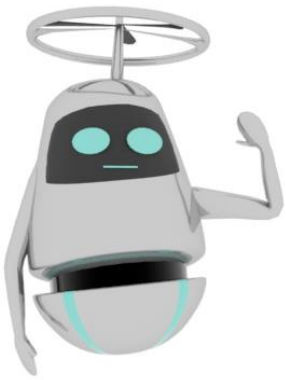
The Process
Of
Designing a Rehabilitation Agent


Bachelor Thesis

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Abstract

The motivation and engagement of the patients is essential when performing physical therapy exercises for rehabilitation. The company HoloMoves makes serious games that aim to improve the motivation and engagement of its users. A virtual agent can be a useful addition to their serious games since an agent can provide information and motivation to stimulate the user to perform physical exercises. This project aims to develop a virtual agent for the game worlds of HoloMoves made for children, by focussing on the tasks, the embodiment and behaviour of an agent. First, the context of a suitable agent and therapy-related aspects were explored, by use of literature research, related work, interviews with client, expert and children. This resulted in different tasks of the agent. Next, the project researched potential embodiments by developing the Design Card method and evaluated existing agents with experts and children. This steered the design process into the direction of robotic characters. The ideation phase developed three robot designs, after which it looked at form-specific behaviour of these three shapes. Next, the realisation phase implemented the three designs into the HoloLens for the evaluations with a total of five children. The evaluations results showed that the mechanical robot, with a robotic appearance and human-like elements, was preferred most by the users. They enjoyed his energetic and motivational look and stated that he would be suitable to explain information and exercises. However, his likeability and animacy should improve by implementing the number of small movements, the smoothness of his actions, the number of simultaneous movements, the number of energetic animations, the movement of the face, and the responsiveness of the robot. This would improve the abilities of the agent to connect with the user, welcome him into the game world, provide information and motivation and activate the user to move.

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1. Introduction

Traditional rehabilitation is often considered as repetitive and boring, even though patients must be motivated and should perform their exercises regularly to improve their health. Serious games have the potential to be successfully applied in this field since they can increase the motivation, engagement and enjoyment of patients [9, 10]. To assist patients in the virtual worlds of serious games, virtual agents can offer guidance and assistance [3]. However, it strongly depends on the implementation of the agent, whether it is effective or not [5, 7].

The company HoloMoves works with the Hololens and develops virtual game worlds, where the user can practice physical exercises. A virtual coach can be implemented in those worlds to assist the user. This coach or digital agent helps the user throughout the session. The agent will introduce the user to the virtual environment, explain the rules of the game, inform the user and guide the user through the games. However, it is unresearched how this agent should behave and look, to assist in such a world effectively.

Virtual agents in the medical field can, for example, focus on coaching people on their health. These virtual agents make use of relational behaviours to create an empathic relationship with their user and have the potential to improve the physical activity level of the user [11]. However, this research showed that virtual agents sometimes miss the connection between the user, the technology and the stakeholders. Therefore, this project will include a human-centred design process which includes stakeholders and users [11].

The goal of this thesis is to develop a virtual agent who can successfully assist users of the HoloMoves games. The users of these games are young patients that stay in a rehabilitation centre for a longer time. Therefore, the main research question will be:

"How to design a digital game guide that can assist children by introducing them to virtual environments, where they implicitly provide information and motivation in a non-therapeutic way in the context of a long hospital stay?"

Therefore, this project will aim to answer this research question by emphasising the design process that leads to this answer. It will start with literature research to analyse the features and functions of virtual agents. Then, a total of 24 existing agents from both scientific and commercial sources are analysed. Next, the project will perform interviews with children, teachers and therapists to examine existing physical therapy sessions and the concept of the agent. Next, the data from the related work is transferred into the Design Cards system and evaluated with users. This card method visually shows the characteristics of each agent and offers a quick way to take in the information. After this, the ideation phase of the project develops multiple concepts of possible embodiments of the agent and will continue with their form specific behaviour. Next, the realisation phase will develop a selection of these concepts further into animated 3D models. The stakeholder and children within the target age then evaluate and test the prototypes. The report will conclude with a final design and future recommendations, but further implementation lies beyond the scope of this thesis.

2. Methods and techniques

This chapter will describe the further structure of this thesis. The overall structure of this thesis will focus on its design process, and it will use the phases and techniques from the Creative Technology Design Process as a guideline. The following section first explains the Creative Technology Design Process, and it will continue by reflecting this to the design process of this thesis.

2.1 The Creative Technology Design Process

The Creative Technology Design Process describes a set of design methods often used in the bachelor's programme Creative Technology [6]. Two existing design approaches are key elements in this process: the Divergence and Convergence Model, and the Spiral Model. The first describes two phases of the design process, where the Divergence phase explores and defines the design space and generates a lot of concepts. The converging phase narrows the design space again until it reaches one solution. The second model, the spiral model, allows for iterations and traversable design steps since it does not follow a logical step order.

The Creative Technology Design Process consists of four different phases: Ideation, Specification, Realisation and Evaluation (figure 1). The Ideation Phase generates ideas and concepts and will result in potential solutions. The Specification Phase continues by further specifying a selection of concepts from the Ideation phase, and it includes some evaluation and feedback. The Realisation Phase focusses on building and implementing the specified concept. During the last phase, the Evaluation, the implemented solution is evaluated and tested with users.

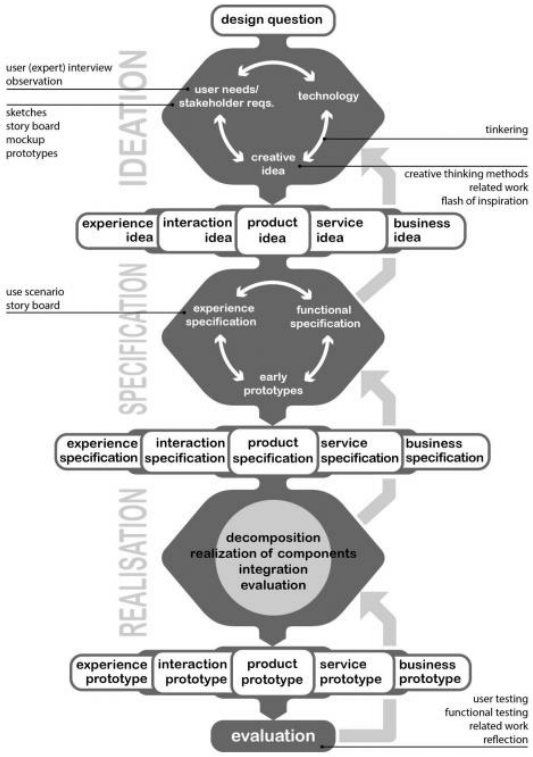


Figure 1: The Creative Technology Design Process, source: adapted from [6]

2.2 The Design Process in this Thesis

This thesis develops a virtual agent by going through different steps of the design process. The process will flow from task to embodiment to behaviour. Each stage will result in outcomes that serve as input for the next step. This means that the thesis will first explore the different tasks and functions that the agent should fulfil. These tasks will then lead to different concepts of the embodiments of the agent (Figure 2). The embodiment of the agent then leads to different types of behaviour that the agent can perform. After the completion of this process, the thesis will look back to see if the behaviour supports the earlier stated tasks.

This design process can implement the structure of the Creative Technology Design Process to structure the course of the thesis. However, it makes some small adaptions regarding the Specifications phase to fit this project better. Instead of a Specification phase, this project embedded a Selection phase into the ideation phase, which evaluates the concepts with the stakeholder.

Figure 2: The Design Process of this thesis

Context Analysis
The context analysis phase will use literature research, related work and interviews to research aspects of an agent and physical therapy sessions. This will provide an answer to the question of what functions and tasks the agent should perform.

Ideation
The Ideation phase will generate concepts and ideas about the embodiment of the agent. It will use the found tasks and requirements to steer the ideation. The ideation phase will first look at existing robot designs, after which it will continue with a sketching phase that results in potential embodiments of the agent. By iterations and reflections on the concepts, the concepts of the Ideation phase will develop. Then, the stakeholder is involved in making a selection of the ideas, which will lead to a small number of potential solutions. It will use the feedback to improve the concepts. Last, the ideation phase will explore unique form-specific behaviour for each of the chosen concepts.

Realisation
The third phase will realise the chosen solutions. It will describe the development of the final prototypes, and it will explain the used techniques and methods.

Evaluation
The last part, the Evaluation phase, will test and show the effectiveness of the developed prototypes with children from the target group. An analysation of the results of the user test will lead to conclusions on the different prototypes, after which it chooses a final design solution.

3. Context analysis

3.1 Research questions

To design a suitable agent, looking at existing research and projects can provide helpful insights and lessons from the past. Therefore, this chapter aims to provide an overview of the features and characteristics of existing Embodied Conversational Agents (ECA) from scientific papers and commercial products. This will result in an overview of the different functions and tasks that this agent should perform, and it will give a grounding basis for the design of an agent during later phases.

The above-stated goal translates into the following research question:

"What different features and functions should the motivational Embodied Conversational Agent have?"

Early research has shown that the term 'features' is an overarching term that describes different elements of an ECA. These single elements are the role of an agent, the visual characteristics of the agent, and the functional characteristics. To provide rich information to each of those, three sub-questions where formed that will be answered by literature research. However, target group-specific information is also needed to design a suitable agent during the later phases of this project. Therefore, a fourth sub-question will research the target group through the use of interviews.

1. Which different roles does an ECA often have?
2. What are the different visual characteristics of an ECA?
3. What are the different functional characteristics of an ECA?
4. What aspects should be considered, regarding physical therapy sessions and the agent, when designing for the target group of children in rehabilitation?

3.2 Approach

Both scientific research, related work and experts in the field provide information to answer the research question. The first part of this chapter will analyse the features and aspects of an efficient ECA as researched in scientific papers. The second part will examine existing ECAs and summarise the advantages and disadvantages. This will lead to conclusions on considerable aspects as input for the design process of this project. The third part of this chapter describes the interviews with the stakeholder, experts, and children from the target age and use their expertise to gather information for the research questions.

3.3 Context analysis: A literature analysis

This section will analyse scientific papers about the features and functions of an ECA and their effects on the user. This will provide information on what makes an agent effective and what tasks he should perform, which can be used later in the design phase of this project. Two sections structure this section: the features of the agent, and the functions of the agent. The sub-chapter will end with a conclusion.

3.3.1 The features of the agent

This section describes the features of the agent, looking at its outer and inner side. It first discusses the outer appearance of the agent and explains the effect of user-control and the

impact on the cognitive load of the user. It then continues by discussing the inner side, which describes the personality of the agent.

Appearance

Multiple aspects influence the appearance of the agent. However, overall, an agent is more effective when his presence is more realistic and when he looks more like a human, stated by Behrend et al. [12], and Van Vugt et al. [13]. When the agent seems more realistic, it positively impacts the user engagement and works more effectively. Multiple smaller factors can be adapted to achieve this realism and human-likeness. First of all, gender and ethnicity are two important factors that have to do with the appearance of an agent. According to Behrend et al. [12], the interest of the user and the recall performance increases when the agent is male and if the user and the agent share the same ethnicity. Secondly, the face of the agent is very important since humans have a good ability to display subtle information with this [14]. Research from Xiao et al. [14] pointed out that agents with bright faces were found more successful during communication. They also stated rounder, bigger and happy faces looked more agreeable and extravert, but big bodies and postures seemed more disagreeable. The researchers tested the effects of the face of an agent with the use of an online questionnaire. Results showed that when agents had a face compared to no face, users spend more time to fill in the survey, they made fewer mistakes and more comments. Research from Van Vugt [13] agreed with this and also described positive effects of facial expressions on user engagement. Next, Van Vugt et al. [13] stated that a third-person perspective and the addition of motion are two other appearance factors. This was confirmed by research by Schroeder et al. [15], which showed that animated agents were significantly more effective. Next, Xiao et al. [14] stated that 3D models were seen as more intelligent and therefore contribute to the overall realism. However, they noticed that 3D models are harder to implement correctly. Last, when looking at the shape of the agent, research showed that there was no significant difference on the effectiveness of the agent, between different forms of an agent when humanoids, non-humanoids, humans or a mix was used [15]. A literature review by Kramer et al. [11] showed that agents, as described in scientific papers, often have the shape of an middle-aged African American woman. Other shapes include a white woman or an animal. In conclusion, agents are more effective and engaging if they have a realistic appearance, which can be influenced by aspects of gender, ethnicity, facial expressions, perspective and motion.

The addition of user control over the appearance of the agent can have a positive effect, according to Behrends et al. [12]. The research explained this effect by the self-determination theory, which describes that there are three basic human needs: competence, relatedness, autonomy. The possibility of choice increases autonomy and competence and thereby, the motivation of the user. Besides that, the research stated that users believed the agent to be more useful if they have designed it themselves to justify the effort that it took to create. Results from the study showed that user control increased the effectiveness, the utility and the engagement of the session with the agent. However, the results showed little effects on the learning outcomes. In conclusion, the addition of user control over the appearance of the agent can have a positive impact on the effectiveness and engagement.

The cognitive load of the user describes his ability to receive and progress information into the long-term memory part of the brain. When the user interacts with the agent for the first time, he has to get used to the presence and the appearance. After a certain amount of time, the user gets familiar with the agent and the cognitive load decreases. However, this only happens if the appearance of the agent remains consistent. Besides that, users have to divide their attention between the agent and the information, which is called split attention. The modality principle

describes that the user can handle more load when the information splits between visual and audio. This is the dual-channel assumption, which combines ears and eyes [15]. Therefore, the design of an agent should not only focus on the visual aspects but also on the audio elements.

Personality

Multiple aspects influence the personality of the agent. In general, users are more motivated to learn and participate in the game, if the agent behaves like a human being. This is called the social agency theory [12] [13]. Therefore, the social aspects of an agent can be important when creating an effective interaction between the agent and the user. This 'human-like' behaviour, as described in the social agency theory, can be broken down in smaller pieces, which all individually influence the user. First of all, Behrend et al. [12] stated that users prefer a digital agent with a personality that matches with their own. They also claim that empathy and humour are essential personality factors. Next, Van Vugt et al. [13] stated that intelligence and conversational skills influence how the user perceives the agent.

3.3.2 The functions of the agent

This section explains the different functions or tasks that the agent can perform. It starts by describing what types of tasks the agent can fulfil and how this impacts the user. It continues by looking at the social role of the agent when interacting with a user, how the agent can steer the attention, influence the behaviour of the user, and provide feedback.

Task performance

A framework by Xiao et al. [14] divided that the tasks that an agent should carry out during the interaction by the intent, objectiveness, the domain, focus, timing and other variables such as the duration. The intent describes the proposed learning outcome or the performance routine, where the objectiveness describes whether the agent provides his opinion or nothing but a description of the tasks. The study showed that users were more likely to pick items when the agent recommended them.

Van Vugt et al. [13] described the interaction between humans with a virtual character by the I-PEFiC model. The researchers stated that the user perceives the agent according to three phases: the encoding phase, the comparing phase, and the respondence phase. The first phase talks about the realism of the agent regarding his appearance and personality. The second phase describes the bonding between the user and the agent, which is influenced by relevance, valence and similarity. Therefore, it is important that the user believes the agent to be relevant for the tasks, and feels a connection of similarity. The third phase describes the response of the user, looking at his engagement and satisfaction with the agent. This was mostly influenced by how the user perceives the agent to be relevant to the tasks. Therefore, task relevance is an important aspect that should be taken into account when designing a digital agent.

Social role

The tasks or activities that an agent performs in the virtual world depend on his social role. In general, it is most common that the agent has the purpose of supporting the user [16]. For example, the agent is the sender and the user is the receiver, the agent supplies and the user demands, or the agents helps and the user is the helped. However, these tasks can variate during the interaction phase. There are multiple ways in which the agent can fulfil this purpose.

According to Behrend et al. [12], an ECA can have four different roles: tutor, instructor, coach or peer. Another categorisation was used by Van Vugt et al. [16] who proposed three different roles: guide, teacher or teammate. However, these two categorisations overlap, where Van Vugt et al. divided the guide and teacher role from Behrend et al. into the roles of tutor, instructor and coach. When an ECA has the role of a personalised tutor, he has the potential to increase the engagement of the user and improve the learning outcomes when they are used in an educational setting [12]. Besides that, they can reduce the feeling of loneliness and isolation when they perform the role of a peer or a personalised tutor.

Attention steering

An ECA can steer the attention of the user into different directions, and with this improve task performance and liking [13]. An ECA can also reduce the information- and workload of the user. However, research by Schroeder et al. [15] showed that users of an interface that includes an ECA strongly focused on the agent and less on the surroundings. Participants spend 56% of the time by concentrating on the agent, even when the agent was only a small part of the screen. Therefore, the addition of an ECA has a noticeable impact on the interaction between the user and the interface. The designer should be aware of this impact, when developing the agent and the digital environment.

Behaviour change techniques

An agent can implement behaviour change techniques; as shown by Kramer et al. [11]. This researcher stated that almost all his researched agents contain some behaviour change techniques. The most often used technique was the transtheoretical model, which gives the user educational information based on the current situation or process. Other often-used techniques are motivational interviewing, the social cognitive theory and the behavioural theory. Besides that, agents often use the method of goal-setting [11]. Other techniques include information about the health consequences, problem-solving, social reward, feedback on behaviour, social support and self-monitoring of actions. These techniques can, therefore, serve as potential behaviour change techniques for the agent designed during this thesis.

Feedback

The agent can give the user feedback [12]. Feedback allows the listener to express whether he is willing to listen and participate in the communication, but also if he perceives, understands and accepts the information that is communicated [17]. Besides that, feedback serves as a way to share emotions and feelings that are caused by the situation. Multiple aspects influence the feedback behaviour of an agent. First of all, Behrend et al. and Van Vugt et al. stated that the attitude of the agent towards the user is an important aspect of giving feedback and can be either proactive or responsive [12] [13]. The difference between proactive and reactive agents is that proactive agents offer advice *before* the user asks them, where reactive agents wait until *after* the user requests them for help or advice. The researchers stated that proactive agents increased the information recall, but they found no significant effect on the attitude of the users towards the agent [13]. Next, when the agent is giving feedback, he can do this either verbally or non-verbally [18] [15] [17]. Verbal feedback uses either voice cues or words [17]. Non-verbal feedback is more complicated, and there are multiple ways of delivering this. First of all, the head of the agent can communicate small amounts of feedback, such as head nods, shakes or roles, and gaze [17]. Next, the head of the agent can show different facial expressions and use

gestures with the hands to deliver non-verbal feedback[15] [17] [18]. However, agents use facial and gaze expressions, more often compared to hand and body gestures [11].

Furthermore, timing is an important aspect of the natural communication between humans, and therefore also plays a role in human-agent communication [17]. This can be a challenge due to the amount of interactivity and responses required for a natural conversation with adequate expressions. Research showed that participants often give feedback during a pause between two words or sentences [17]. This phenomenon is called the pause-duration model. The model describes what the best time of giving feedback is during a conversation. Findings showed that feedback often occurs when a low pitch follows a long period of normal pitched speech. Experiments of time modelled feedback also found that when content-related feedback and non-verbal feedback were combined, the communication is smoother. Another study evaluated different ways of how feedback can be delivered and measured the accuracy of the timing [17]. The accuracy of providing feedback after a fixed amount of words turned out to be only 6%, using the pause duration model was 32% accurate, and a combination of the two was 35% accurate.

3.3.3 Conclusions from literature

Research showed multiple factors that describe the features of the agent, which represents the appearance of the agent and the personality. Literature furthermore gave insights into the different tasks that the agent should perform.

The appearance of the agent results in a most effective agent when he is realistic and human-like. This realism includes aspects such as gender, ethnicity, facial expressions, perspective and motion. Besides that, the face is important during communication, and round, big and happy faces are more agreeable. Next, it is effective to implement both audio and visuals into the design of the agent. Furthermore, the addition of user control over the appearance can increase autonomy and competence, which influences the motivation, effectiveness and the engagement of the user. Research also showed that the appearance of the agent should stay consistent as much as possible, to decrease the cognitive load. The personality of an agent is most effective when it resembles a human-like personality. This human-likeness includes aspects of empathy, humour, intelligence and conversational fluency.

For the tasks of the agent, the user must perceive the agent as relevant for the job to be effective. Most agents have the role of helping and supporting the user. The agent can have different social roles, where the role of a peer or tutor can improve the engagement and learning outcomes and reduce feelings of loneliness and isolation. Furthermore, a digital agent effects the focus point of the user in such a way that he is more focussed on the agent than the surroundings. Next, the agent can implement different behaviour change techniques, such as providing information or motivation, setting a goal, providing rewards or feedback, and giving information about health consequences. Next, the agent can provide both verbal and non-verbal feedback, through his voice or by use of the face, gaze or gestures. Last, the agent can communicate with the user about tasks through text, speech or multiple-choice options.

3.4 Context analysis: Related work

This subchapter will discuss related work. The section will start by discussing ECAs that are grounded by scientific papers and follows with agents from the commercial field. The agents are chosen based on their overlap with the earlier found tasks of providing information, motivation, feedback and assistance to the user For each ECA, its features and characteristics are listed and discussed when they had potential value to this project.

3.4.1 ECAs based on literature

The Pergamom project

The PERGAMOM project is a serious game for young patients with diabetes [19]. The agent has the role of coaching the user, and he can keep track of the objectives and achievements of the user. The agent can set daily- or long term goals and send reminders or motivational messages if the user forgets to perform his tasks. This project makes use of different behaviour change techniques, such as providing the user with praising or stimulating feedback, offering awards after the completion of tasks, or giving reminders, notifications or hints.

Figure 3: The Pergamom Agent, source: takodojo.com

The agent has the shape of a 3D animated, cartoonish, animal, and he uses facial expressions, such as blinking and moving his mouth and brows, as shown in Figure 3[1]. The animations use sound effects after each movement. Healthcare professionals formed the content of the agent. The communication from the agent to the user is through text and sometimes with pictures or videos.

An interesting aspect of this agent is his use of different types of behavioural change techniques. Examples of these techniques are goal setting, keeping track of personal objectives and achievements, rewarding, praises, reminders and motivational messages. Since this agent also works in the medical domain and the target group of younger children, he can be a learning example.

Exercise advisor Laura

The agent has the role of an adviser and can provide elderly adults at home with exercises to improve their health [1]. The agent is a 2D model of a woman that is displayed mostly with her upper body (Figure 4). The agent has no continued movements but exists of different fixed positions. Facial expressions make use of the mouth, brows, eyes and face position, and gestures emphasise aspects of the communication. The agent uses speech and non-verbal cues as a communication tool. The user can interact by choosing an option from a multiple-choice list. The agent becomes more personal and social over time, which imitates real human-to-human contact. The agent uses reminders and sets a goal, which gradually improves over time.

Figure 4: The exercise advisor Laura, source: adapted from [1]

This agent aims to stimulate users to perform physical exercises and therefore shows some overlap with this project. An interesting aspect from this agent is that the connection between

[1] https://takodojo.com/nl/ - *image of the PERGAMOM agent*

human and this agent develops over time. The agent will develop socially and personally, which stimulates the contact between agent and human. Since realism of social contact showed to be effective in the literature research, this can be a valuable addition to the agent. The user can interact with the agent by use of a multiple-choice option list. This interaction method is easier to implement than, for example, speech or text. Therefore, it can be an option for the development of prototypes of this project because of the limited realisation time.

The recipe hunter

The agent intertwines with a storyline of a game that focusses on teaching the user about regional traditions through food [2]. The agent used in the game is a model of a 3D woman (Figure 5). The communication between the user and the agent is only through verbal speech and nonverbal body language and uses no buttons, text or notifications. The agent provides the user with assistance, cues and stimulations. However, the amount of feedback depends on the attitude of the user. If the user is unpolite or rude, the behaviour of the agent will change, resembling the behaviour of a real person.

Figure 5: The agent from Recipe Hunter, source: adapted from [2]

The addition of a storyline can create another dimension to the game or application, and can, therefore, be interesting for this project. Secondly, the behaviour of the agent is dependable on the attitude of the user, which can make the relationship between the user and the agent more realistic and human-like. This concept can be added to this project to improve the relationship between the agent the user.

Greta

The agent is used as a coach to provide users with medical information [3]. She is displayed as a 3D model of a woman and has a detailed face with eyes, eyelids and lashes (Figure 6). She communicates with the user through words, gestures, gaze, facial expressions, posture and blinking. Furthermore, the body of the agent assists the spoken language. For example, the agent gets a sad face if she talks about something negative. The agent is positioned in the middle of the screen and is always visible. The user can ask the agent something by speaking out loud, after which he will get an answer or a question in response.

Figure 6: The agent 'Greta', source: adapted from [3]

Altogether, this agent is used to provide information to users in the medical domain, and can, therefore, be of inspiration to this project. The agent uses many different communication tools to transfer the information, such as her face and her body.

Tinker

Tinker is an agent that is used in a museum as a guide to give instructions and information [4]. Research showed that he has a positive effect since the engagement of visitors improved, and they tended to visit more often and stay for longer. The appearance of the agent is an animated, humanoid robot character (Figure 7). The agent can move his body, arms, face and head to provide the user with feedback. Besides telling information with a computer-

Figure 7: The Tinker agent, source: adapted from [4]

generated voice, the agent displays the same text in an additional textbox. The agent made use of empathy and humoristic wording in his communication.

Overall, the agent showed to be effective in increasing the engagement and knowledge of the users, and its aspects can, therefore, be potentially useful. The robotic shape of the robot, his behavioural feedback movements and use of empathy and humour can be inspirational input for the design of this project.

Alice in wonderland

The agent has the goal of providing information to the user [8]. The agent has a big head with a large mouth and eyes, and she uses this to give feedback through facial expressions (Figure 8). Other feedback uses gestures and body movements. The big facial characteristics emphasise the feelings and emotions of the face. Furthermore, the agent has the shape of a younger girl, and the model is cartoonish and animated. Lastly, the agent introduces herself by explaining her purpose to the user through verbal speech in combination with non-verbal movements.

Figure 8: Two different positions of 'Alice', source: adapted from [8]

Both the emphasised facial features and the introduction from the agent herself can be an inspiration for this agent. They strengthen the liveliness and smoothness of the character and increase the impact of her facial expressions.

Alice

Alice is a digital journalist, which had the purpose of engaging the user in natural conversation [7]. The agent has the shape of a woman and uses verbal and non-verbal cues for the communication (Figure 9). Furthermore, the agent aims to respond to the user and ask return questions emotionally. However, the research evaluated the agent as not engaging. This was mostly because the agent seemed to lack a deep understanding of the presented information and failed to show correct emotional responses. The character itself was liked but was found generic and unmemorable.

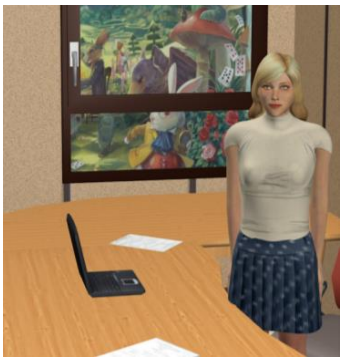


Figure 9: The agent 'Alice', source: adapted from [7]

Overall, this research showed a responsive conversation between the agent and the user has to feel natural. Otherwise, users will evaluate the agent negatively. Furthermore, users liked the shape of a woman but found this not special or outstanding. Therefore, these two negative aspects of the agent can serve as a lesson for this project.

Council of coaches

This collection of agents works together to provide adults with coaching services [20]. The different men and female models are all in 3D and displayed with their upper bodies (Figure 10). The agents communicate by speech and use different facial expressions and movements to accompany this. Each agent has diverse expertise, personality and appearance, with a voice that matches the gender and looks. With these different points of view, they provide a well-

Figure 10: A screenshot from the different coaches, source: council-of-coaches.eu

considered coaching service. Each agent turns his head and upper body towards the attention point, however, no other movements or gestures with arms or hands are used. The user can communicate with the agents by selecting an option from a multiple-choice list.

Overall, interesting about this collection of agents is that they all have a different, expertises and personalities, which makes them unique and different from the others. Giving the agent distinctive character traits and personal stories can, therefore, be a way of making him look more human.

Echoes

This agent serves as an assistant in a serious game for children with autism [5]. The goal of the agent is to be both a tutor and a peer for the children. In the development of the agent, it showed that a cartoonish, animated boy-like agent was most effective for the users from the target group since this was more familiar and fun to the user (Figure 11). The head, eyes and hands are bigger, so that information displayed with the body is easier to perceive for the user. Furthermore, the agent needed to be spontaneous and human-like in his communication. Therefore, he made use of verbal and non-verbal feedback, by the use of facial expressions, gaze, body position and gestures. All feedback aims to be positive and constructive.

Figure 11: The agent used in the game ECHOES, source: adapted from [5]

Children are the target group of this agent, which overlaps with this project. The research on the appearance of the agent can, therefore, be usable for this project. The appearance adapted to the target group, by increasing the size of the head, eyes and hands. Next, the body could point and steer the attention of the user into the preferred direction.

3.4.2 Commercial ECAs

The following section describes the commercial agents that an internet search yielded. These results are well-known and often appeared in the search results or were suggested by the stakeholder or a child.

Eliza

Eliza is a web agent[2] who focusses on having a responsive conversation with the user. The agent is a 3D model of a woman and only shows her upper body (Figure 12). The agent moves continuously and uses small movements like blinking, eye movement, head nods or tilts, and mouth movements. The agent has a computer-generated voice and speaks with complete sentences. Feedback is given through small changes of the head and mouth, and by verbal responses.

Figure 12: A screenshot from 'Eliza' source: webglstudio.org

This agent strongly focusses on having a responsive conversation with the user and implements aspects such as blinking, eye movements, head nods or mouth movements. This can be interesting for this project to have an engaging conversation with the user.

[2] https://webglstudio.org/gerard/eliza/ - *the web agent Eliza*

Arial

The agent 'Arial' is part of a typing course for children, and he has the function of being a buddy and coach to the user [3]. The agent is a 2D, cartoonish drawing of a young boy, and he uses gestures and hand positions to emphasise and show certain emotions (Figure 13). The agent has no movements but uses fixed positions that fit the conversation. The agent can show positive feedback through positive words, facial expressions and sound effects. The agent communicates through a textbox and additional pictures or graphs, and aims to give the user small tasks and goals to perform that are part of the story.

Figure 13: A screenshot from 'Arial'; source: typetopia.com

The target group of this agent matches with this project, and can, therefore, serve as inspiration. Especially the function of being a buddy or a coach to the user can be input for this project. Besides that, the character gives the user small, achievable tasks that contribute to a storyline.

Clippy

'Clippy' was used by Microsoft to assist users in using Microsoft programs[4]. The agent is a cartoonish 3D model of a paperclip object (Figure 14). The agent uses small movements of blinking with the eyes, which are alternated with sudden, random animations where 'Clippy' performs a specific action. The eyes can steer the attention towards parts of the screen. Furthermore, the agent communicates with the user by text and buttons and small sound effects.

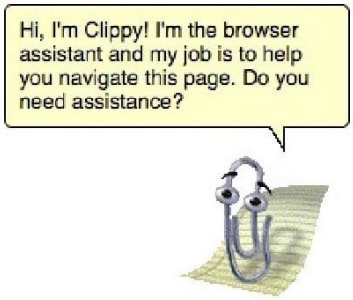


Figure 14: A screenshot from 'Clippy' , source: mentalfloss.com

This character increases his liveliness by showing small and sudden animations, which can serve as input for this project.

Evi

'Evi' is an agent used for an online banking service[5]. She has the goal of advising and providing help to users when they are using the service. The agent is a 2D model of a woman (Figure 15). She has a simple shape with little details and displayed through both animated movements and fixed positions. The agent communicates through text and a female voiceover, and she gives feedback through hand gestures, body position and mouth movements.

Figure 15: A screenshot from 'Evi', source: evivanlanschot.nl

This agent has a simple shape, with only the essential parts. This gives a more aesthetic look and shows that details are not necessary to create a realistic appearance.

[3] https://www.typetopia.com/en-GB/ - *the typing assistant for children*
[4] https://www.mentalfloss.com/article/504767/tragic-life-clippy-worlds-most-hated-virtual-assistant
[5] https://www.evivanlanschot.nl/beleggen

Hop

'Hop' is a character from the Pokemon Swords & Shield game [6]. He has the goal of assisting the user throughout the storyline of the game and guiding the user into specific directions. The character is displayed as a buddy and coach and has the shape of a cartoonish boy with big eyes and a friendly face (Figure 16). The character only has a few fixed positions throughout the conversation. However, continues movements are used to make the character look alive, such as breathing, mouth movements and hair movements. The character uses his body, face and eyes to steer the attention during a conversation. Furthermore, the user can communicate with the character through text and buttons, and give feedback through hints, tips, praises and information about the current situation.

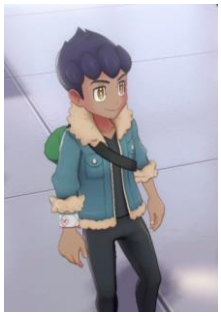


Figure 16: a screenshot from the Pokemon Swords and Shields game, source: swordshield.pokemon.com

This character uses small, continues movements to increase the liveliness, such as breathing or hair movements. This can be an inspiration for this project to make the agent more alive in between actions.

Anna

IKEA developed this agent to answer IKEA related questions from website visitors in a fast and efficient way[7]. The agent has the appearance of a cartoonish, 2D displayed woman (Figure 17). The character is not animated, but uses small head movements and blinking of the eyes at an interval to increase the liveliness. The agent sits at the corner of the screen and can be removed at any time by the user. However, users evaluated the agent as inefficient and incapable of correctly helping IKEA them. Therefore, IKEA disabled the agent and is no longer in use.

Figure 17: A screenshot from the IKEA agent 'Anna', source: chatbots.org

This shows that the agent should be capable of carrying out its proposed tasks to prevent unsatisfaction and irritations from the user. However, the agent shows that small movements and blinking of the eyes can increase the feeling of the liveliness.

Lena

This agent assists a chatbox service from the Lenovo website, which can answer customer questions[8]. The agent has a static, simplistic appearance of a cartoonish robot (Figure 18). The robot uses a looped movement of moving up and down and slow blinking of the eyes. The agent greets and welcomes the user, and asks him questions.

Figure 18: A screenshot from the Lenovo agent 'Lena', source: lena.lenovo.com

Overall, the agent shows the be simple in design. However, small repeated movements, such as blinking and moving up and down, can increase the liveliness of the agent. Furthermore, the shape of the robot is simplistic and uses little detail, but it is still able to convey the feeling of an assisting character.

[6] https://swordshield.pokemon.com/en-us/
[7] https://www.chatbots.org/virtual_assistant/anna3/
[8] https://lena.lenovo.com/lena

Sara

The agent has the goal of providing information to the users during conferences and at the same time, maintaining a social relationship with them[9]. The agent is a 3D, cartoonish modelled woman, and she is wearing formal clothes with glasses (Figure 19). The model is only visible with her upper body. The model uses motion in her arms, hands and head to express herself. Furthermore, the agent provides the user with feedback through gestures, head nods, the blinking of the eyes, smiles and posture shifts. Small movements are combined, such as change is brow position and rotation of the head, to convey emotions or strengthen the verbal communication. Furthermore, the user can communicate with the agent by visual and vocal cues.

Figure 19: The agent 'Sara', source: articulab.hcii.cs.cmu.edu

Overall, the small movements of the agent, such as head nods or rotations and facial movements, increase the communicational strength of the agent. This goes together with gestures from the hands and arms to transfer a message.

CozE

This agent has the goal of answering questions of the costumers of the CozE website (Figure 20) [10]. He has the appearance of a stylised, 2D cartoonish flame without a body, arms or hands. The model has no face or other human likeness, gender or movements. The communication uses a text box, where the agent asks the user responsive questions. The agent uses a pausing model in between his answers, where small dots represent his typing and thinking behaviour.

Figure 20: A screenshot from the Coze chat box logo, source: enbridgegas.com

Overall, the appearance of the agent has no liveliness or human-like aspects. However, his communication through text uses a pausing model, to simulate a thinking and typing behaviour, which increases the feeling that the agent is human-like.

Duolingo

The language learning application 'Duolingo' uses an owl as a mascot[11]. The owl has the goal of persuading the user to perform his daily exercises to improve his language skills. The character has the shape of a simplified, cartoonish animal shape with vibrant colours and a large head compared to his body (Figure 21). The shape has no motion besides small blinking movements of his eyes but alternates this with animations of, for example, waving to the user or a walking cycle when a screen is loading. Static facial expressions convey an emotion that fits the textual conversation. Furthermore, the owl uses awards when the user achieves success and gradually reveals more options from a progress path. Reminders notified the user when he didn't perform his exercises.

Figure 21: The Duolingo mascot, source: duolingo.com

Overall, the Duolingo has the goal of activating users to perform exercises, which fits with this project. Therefore, the behaviour change techniques, such as rewarding, reminding and path revealing, can be considered as useful for this project. Furthermore, although the mascot of the application is not animated, small, periodic movements can increase the feeling that the character is a living animal.

[9] http://articulab.hcii.cs.cmu.edu/projects/sara/
[10] https://www.enbridgegas.com/Coze
[11] https://www.duolingo.com/

Young Conker

This agent has the goal of guiding the user through an AR game environment while providing them with information[12]. The agent is used as a peer- and coachlike figure meant for children or gamers. The agent has a cartoonish animal shape and is visible with his full body in 3D (Figure 22). The character uses many movements such as gestures, head nods, facial expressions, which are varied by fixed animations of the agent falling or performing a small dance. The agent uses a 'real' voice that matches with his appearance and provides the user with tasks, instructions and information during the game. His verbal instructions are accompanied by visual arrows or signs to explain the task further, and he uses non-verbal and verbal feedback to guide and steer the user. The user can interact with the agent by movement, gestures and speech.

Figure 22: An in-game screenshot from the 'Younk Conker', source: microsoft.com

Since this game uses the HoloLens, it has an overlapping aspect with this project. Therefore, the way of interacting, through movement, gestures and speech, can be of inspiration to this project. It also makes use of the environment to implement arrows or signs. Furthermore, the game is meant partly for children and uses a cartoonish animal-like appearance with different 'funny' alternative animations, which could be considered in this project as well.

Fragments

Fragments is an AR game where the user has to behave like a detective to solve a murder puzzle[13]. The agent used in this game has the goal of a coach and provides information and instructions to the user. The agent is a 3D model of a man, where his whole body is visible and aimed to look realistic (Figure 23). The body and eyes focus on the user and following him whenever the user changes his position. Furthermore, facial expressions and body movements are used, such as gestures, shifts in posture and head nods, where these small movements, such as the blinking of the eyes or scratching on the cheek, are implemented to increase the liveliness of the character. The agent provides tasks, information and instructions to the user. During the beginning of the game, the agent offers the user with an easy problem and explains him to solve the small mystery, to make the user understand the context and the way the game works. Whenever the agent appears or disappears, particles show the transition between visible and invisible.

Figure 23: The agent used in the 'Fragments' game, source: asobostudio.com

Overall, the agent efficiently introduces the user to the game by proposing a small and introductive mystery to the user. This directly makes it clear to the user what the game is about and explains the procedure of the game interactively. Furthermore, the liveliness of the agent increases by adding small movements, such as scratching the cheek or blinking.

[12] https://www.microsoft.com/en-us/p/young-conker/9nblggh5ggk1?activetab=pivot:overviewtab
[13] https://www.asobostudio.com/games/fragments

Grasshopper

The agent from the application 'Grasshopper', which teaches programming skills, has the goal of providing the user with instructions[14]. The agent has the appearance of a 2D, stylised animal (Figure 24). Fresh colours focus on creating an aesthetic atmosphere, where all elements fit together to the overall style. The agent has a simple and happy face but uses no further facial expressions or movements. All communication is done through text and visual images and aims to give the user tasks and instructions. The user receives praises for his work through text and sounds, and particles provide additional feedback.

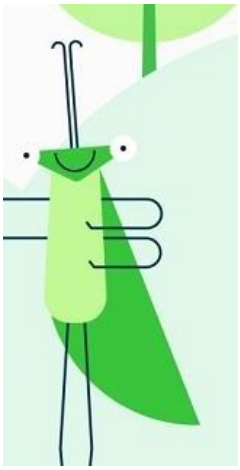


Figure 24: The agent used in the 'Grasshopper' app, source: grasshopper.app

Overall, the agent has a simple, non-moving shape, but uses text, additional particles and sound effects to communicate with the user. A significant aspect of the application is the attention to the overall aesthetics, where all aspects follow the same colour scheme and style.

Clumsy ninja

In the game 'clumsy ninja', the user can control a ninja that has to learn different skills[15]. The character is guided by a 'ninja master', who provides the user with tasks that he should perform to train his ninja. The master figure has the appearance of an older man and is showed as a fixed image where only his head is visible (Figure 25). The character uses no movements, and he communicates with the user through text, where the user can only press the okay button if he understands the provided information. The character can be easily pressed away by the user, after which becomes visible as a small icon in the bottom of the screen with a small, pulsating circle around it. Furthermore, the agent gives feedback by textual praises and rewards. The progress that the user has made so far is visible in a progress path.

Figure 25: The agent used in the Clumsy Ninja app, source: wired.com

This character fits with the context of the game and provides the user with tasks and instructions. After completing specific tasks, the user can see his progress on a visual 'road map'. The character is only visible on full screen when a new job is given and is visible as a small icon during the rest of the time.

2.4.3 Conclusions from related work

The aspects of the different agents are combined in a table to create an overview of all possible features (Appendix A). Some elements often occurred and can serve as a guiding line for the development of the agent of this project. This section will continue with conclusions that follow from this table.

First, ECAs used for children often have the shape of a young boy or an animal. However, on a general level, earlier stated research found that most ECAs look like a woman. Secondly, the goal of an ECA is context-specific, and for this project, it would be most fitting to use the role of a coach or an adviser. Furthermore, there was an approximately even division between 3D and 2D ECAs. However, almost all ECAs used in a game environment were 3D. Besides that, nearly all agents made for the target group of children used motion and used their full-body, where agents from other target groups also used no movement and showed only the upper body. The majority

[14] https://grasshopper.app/
[15] https://www.wired.com/2014/02/clumsy-ninjar/

of the agents made use of gestures with mostly both the arms and hand. Almost all agents, especially in the target group of children, were found to be both cartoonish of style and animated. Next, communication often uses buttons or multiple-choice options. Fewer cases used speech or text. Next, the majority of the researched agents used behaviour change techniques. Most commonly found were the methods of goal setting and information displaying, and other techniques such as awards, praises, reminders and path revealing. Furthermore, almost all researched agents used facial expressions in their communication with the user. Most often found aspects were eye movement, blinking, mouth movement, eyebrow movement and head nods, where eyes appeared most commonly. Furthermore, the majority of the agents were able to provide the user with feedback, which was delivered through text or in non-verbal ways, such as expressions, gaze or posture. In a few cases, the agents used sound effects as well. Often used was the ability to give advice, instructions, hints, task providence, or information. Furthermore, the majority of the agents didn't have a voice. When an agent used a voice, this was often a computer-generated voice that matched the appearance of the agent.

3.5 Context analysis: Interviews

This section will further research the context of the agent, what is needed and provide key points that the design should take into account. Therefore, it will describe the performed interviews with the client, experts and the children from the age group. It will first describe multiple conversations with the client. This focusses on the design process and the making of different choices. It also concentrates on shaping the knowledge about the target group so that later phases can design with more empathy and understanding. During the second part, it will explain the interviews with experts and children with the target age that focused on therapy sessions and the concept of the agent.

3.5.1 Contact with the client

Contact with the client would result in more insights on the scope of the project, the agent and the target group. Therefore, this project conducted three meetings at the office of the company. The following three sub-sections below show the results of the sessions. First, the scope of the project sets the potential target group and the desired end goals of the thesis. Next, the research on the agent focusses on the considerable elements during the design phase. Last, research on the target group will provide more insights and empathy that can help to better design for this group of users. Three meetings with the client resulted in answers to those topics. Two of the meetings took place at the office of the client, and the last meeting scheduled a visit to the rehabilitation centre.

Setting the scope of the project

The first meeting discussed the initial plans of the thesis. HoloMoves works for multiple different groups of people, for example, for children or elderly users. However, this project chose to focus on children, aged 12 till 16, in a rehabilitation centre for an extended period.

Secondly, the conversation discussed the outcome goal of the thesis. Options were, for example, to design an interactive exercise game for children, to work on an existing game environment, or to work on the addition of an avatar for the games. Together with the client, the decision was to focus on creating an avatar. In this way, the project is a stand-alone project and can be

developed independently of the other projects of HoloMoves. It also allows the company to reuse the designed avatar for the target group of children to different target groups and domains.

Third of all, the decision for this younger target group sparked some initial ideas for a design. One of the game worlds that has already been developed by HoloMoves is a world called 'Boris Wereld'. Ideas that came up where 3D shaped characters. For example, a teddy bear or a doctor. The view from HoloMoves described the figure as if it was a 'buddy' that would walk into the room and would play together with the child. The character was described as a friend and helper while they together find their way through the game environment. Besides that, ideas came up about using small movements in the design to increase the liveliness, such as small head movements, blinking eyes or breathing movements. Other potential aspects of the agent are his ability to communicate or talk. For example, he could have a 'real' voice, a robot generated voice or only communicate through text or images.

Fourth of all, the company named three crucial points of their games: motivation, activation and information. Therefore, the avatar of this project should include these three aspects, as well. This means that, besides stimulating the child to perform exercises, the avatar should also provide the child with educational information.

Defining the concept of the agent
During the next meeting, the frame of the project became clearer. It focused on looking closer to the concept of an agent. This concept exists of multiple sections: the liveliness of the agent, the abilities, the appearance, and the goals.

First, the liveliness of the agent would describe how much he would appear to be a living creature. An idea that came up was to use motion tracking of real humans and implement the movements into the agent. This Godspeed questionnaire can evaluate this liveliness during the evaluations later in the project[16]. Secondly, the abilities of an agent would include his behaviour, his way of transferring information, personalisation of the agent and the interactivity. Next, the appearance of the agent included questions about his shape, gender, age or whether he would look like a human, animal or robot. Last, the goals of the agent talked about what the agent could achieve. For example, he could give educational information, give feedback and guidance, or he could be motivational to the children. HoloMoves stated the importance of guiding, leading the way and explaining information.

Research on the target group
The rehabilitation centre 'De Hoogstraat' was visited during the third meeting with HoloMoves. This resulted in more knowledge about the rehabilitation centre and the target group.

The rehabilitation centre uses multiple different sections. It contains a workshop, which develops all kinds of prosthetics, wheelchairs and other medical instruments. People were working to alter the rehabilitation products completely to their patients. For example, a wheelchair is entirely personalised to the structure of the backbone of a patient. Overall, each product focusses on assisting the user so they can continue their life. The centre also included a treatment section for physical therapy. This included a sports hall for games and exercises and a swimming pool.

[16] https://www.bartneck.de/2008/03/11/the-godspeed-questionnaire-series/

Besides that, there are multiple sections where the patients are staying for a more extended period, ranging from days till weeks. Adults and children are split up and stay in different parts of the rehabilitation centre. Since this project focusses on children between the ages of 12 and 16, so the visit concentrated on the children section.

The children section includes all elements to continue the daily life of the children as normal as possible. This includes school, treatment sessions, leisure times, visits from friends or family, cooking and eating, and sleeping. Most children from this section are young children, aged until 18. After this, they move to the adult section. The reason for their stay is very different and can variate from days till weeks or months. Their illness can have a traumatic reason, such as a car accident, or a chronic reason that has been present since birth. The complete treatment focusses on improving the health and abilities of the children so they will be able to can continue their lives at home. During their stay, they mostly stay in the centre. Family and friends can visit at specific moments in time, or a family member stays over to take care of them. They can have social contact and play with other children that are also staying at the rehabilitation centre.

The children follow, where possible, their normal school rhythm when they are staying at the rehabilitation centre. In this way, they will be delayed as little as possible in their school track when they return home. Besides school, there are many other activities they can do. For example, there is a 'living room' area, where they can play games or relax with each other. Besides this, all the treatment rooms are in the same area, and they can quickly go from there to their private rooms. There is also a kitchen area, where the children can bake and cook. A regularly made recipe are cookies since this trains the hands and arms when you are kneading the dough.

The children have their own room or share this with one other patient. The room includes the basics like a bed, bathroom and closets. However, all things are adapted to be fitting in a rehabilitation centre. The bed has multiple medical devices to make the care and mobility of the patient easier, and the bathroom is adapted to be easily useable for patients in a wheelchair. The rooms of the patients are spacious enough to perform exercises with the HoloLens. However, there would be some placement issues since there are some windows that could disturb the light in the room.

The overall goal of their stay is to improve their health so they can return home again. During the treatment process, small steps focus on reaching this goal, but all under the supervision of their doctor.

3.5.2 Interviews with experts and children

Interviews focus on providing more information on the context of physical therapy and the potential usage of a digital agent. They will produce insights and requirements on the current way therapy is being done and requirements of the agent for the later design phase of this project.

Goal

The interviews aim to provide two main results. First, it will gather information about the current way of doing physical therapy with children. This includes aspects such as the motivation of children, pitfalls of working with the age group, and different approaches that a therapy session can use. However, the expertise of the therapists can also result in information

that this project did not consider yet. Secondly, the interviews with the experts and children will result in insights on their preferences on the agent regarding his appearance, behaviour or tasks.

Participants

The project approached a total of three physical therapists, one physical education teachers and five children to participate in the interviews. The therapists work for a rehabilitation centre or a Cesar clinic with a focus group of children. They all aim to improve the health of children by moving and performing physical exercises with them. The physical education teacher works with children from high school, where the focus is on teaching and motivating the children to move. The children are from the age group 12 till 17 and most of them, except one, had no experience with rehabilitation.

Setup

The interviews took place digitally through a Skype video call. The participants could schedule the meeting according to their preferred time.

Methods

Both experts and children participated in the interviews. Therefore, the interview used two different sets of questions to match the level of the participant and their expertise (Appendix C). Both versions used a semi-structured approach and a scenario description. This scenario aimed to give the participant a feeling of the potential use of the HoloLens.

Before the interview started, it briefly explained the project and the general procedure, and the participants were asked to sign the Informed Consent form (Appendix B). Then, the interview of the experts began with physical therapy related questions. After this, the interview explained the scenario and continued with scenario-related questions. The interview for the children started with the scenario and continued with the scenario-related questions. The scenario is the same for both the children and the therapist, but the two versions use different questions.

Physical therapy-related questions for the experts

1. What techniques do you use to motivate the child?
2. How do you motivate the child to keep going during a therapy session?
3. What do you do when the child does not want to continue?
4. Are you present during the session?
5. Do you explain the exercises beforehand? In what way?
6. On what things do you pay attention during your explanation? How do you notice if the child understands you?
7. How do you make sure the child can learn and improve optimally?
8. In what way do you give feedback, and when?
9. How do you communicate it when the child needs to improve something?
10. What are important aspects to take into account during the sessions or when working together with children?
11. What attitude do you have towards the child?

Scenario
Nils is a fourteen-year-old boy that just finished third grade from his highschool. He has to perform a walking exercise because he had a car accident a couple of weeks ago. The exercise asks him to walk in a straight line, where the stepsize slowly increases.

Nils is sitting in the office of his therapists. He takes the HoloLens from the desk and carefully places the glasses on his head. All of a sudden, the room transforms into the widely spread landscape of the Grand Canyon! He can see the sun shining in the distance, and he hears a few birds whistle softly. He sees something moving in the corner of his eyes. He turns around and sees the agent coming towards him. The agent welcomes him in the Grand Canyon. He explains that Nils has to play a game where he needs to cross a big river. In the game, he has to walk over an old bridge, where some of the wooden planks are rotten. The agent warns him that some of the steps are a bit larger than the others.

Scenario questions for the experts

1. How do you envision the agent?
2. What are the different tasks that this agent will perform?
3. How does the agent behave? Think about expert, doctor, friend or brother.
4. Is the agent always present?
5. What are some requirements that the agent has to fulfil?
6. Is the agent helping during the exercise?

Scenario questions for the children

1. Envision the scenario in your mind. What does the agent look like?
2. The agent comes towards you. What is the agent saying to you?
3. In what way is he coming towards you?
4. What is your relationship with the agent?
5. You have to perform the exercise. Is the agent helping you, or are you alone?
6. What are some unique or exciting things that this agent has?

Results of the therapy-related questions

Motivation techniques
As stated by multiple participants, the child must enjoy the situation and the exercises that he has to do. Therefore, the tasks should match the level of the child. It differs for each child, whether the level should be higher or lower. Some children need fast successes to stay motivated and therefore require a lower level. Other children need a challenge and therefore need a higher level. Besides that, in rehabilitation, some children need to rebuild trust with their own body and therefore need a lower level to experience successes. So, overall, children are more motivated to move and exercise if they experience success.

The virtual environment and the exercises match with the imagination of the child. By adapting the situation, the motivation and interest of the child will increase. To discover the interests of the child, often an initial meeting is done with the child and its parents. This meeting discusses

topics like what toys he likes to play with, or what he likes to do at home to build as inspiration for the therapy session.

Therapists try to use a lot of humour during their sessions, or explain the exercise in a non-traditional way, like creating a game or an adventure. This can make the child enthusiastic and intrigued. Furthermore, it is beneficial if there is something in return for the child, for example, a 'punishment' for the therapist, rewards, points, or an extra game level. This confirmation on when the child reaches a goal has is extra motivational for them. Besides, it is effective to give the child input on what the reward or punishment of the bet will be. In this way, the child can experience some control over the situation. Besides that, the game could adapt the levels to influence the motivation of the child. They could range from easy to hard, from short to long, or from slow to fast.

The participants rated the HoloLens as having potential since the child can use the Hololens by himself. This can have a positive effect that the child can feel very independent. The child can perform the exercises from the virtual world alone, and the choices are all made by himself. This is valuable since, especially in rehabilitation, there can be certain things that the child cannot do in the real world yet, but are possible in the game world. Therefore, the glasses can give the child a positive feeling of independence, which is often important for the age group of 12 till 16.

If the child has no motivation anymore, it strongly depends on why this happens. It is often the case that the exercise is too hard, or the child is unable to complete it. For example, if the task is exhausting for the child or when he needs to train weak muscles. In these cases, it helps to talk with the child about what he thinks about the exercise, what he would want to learn or what else he would rather do. It can also help to lower the level of the activity or offer some extra help. Besides that, it can also help to give the child some options and let them chose. In this way, they can experience control over the situation. The choice can also 'trick' them into choosing one of two acceptable options. Furthermore, it can help to create a bet out of the situation so that the child will get motivated.

Therapy goals

Goals can structure a therapy session. There are a few end goals which describe what will be achieved by the end of the therapy. The end goal provides multiple sub-goals to make it more tangible. However, it first needs to be determined what the child can do at the current moment. Therefore, the child has to perform a certain exercise or game to see what he can and cannot do. But also topics like what the child wants to learn, what he wants to be able to do, and his personal goals are of influence.

It is also possible to set small goals for each therapy session. Overall, session goals should always be achievable. It is very motivational to the child if he has a successful experience after each session. In this way, the child feels like it will be enjoyable to come back the next time and to try something harder. At the end of each session, it can help to give a small preview by already explaining what will happen the next time.

Exercises

The type of explanation is very dependent on the learning entrance of the child. Most of the time, it works very well to visually show the exercise with the body for children with a low language level or that are visually strong. Children that can understand spoken language very well can follow the tasks from an explanation. However, often when a situation is more complicated,

children will mostly use their most reliable sense organ, which is usually their sight. Therefore, visual explanations with examples or icons work best in this situation.

Some children need an apparent structure in the explanation and therefore require a very clear begin and endpoint so that they have an overview of what is going to happen and how long it will take. The language used must be simple but not childish, and understandable for different levels of children. Therefore, it is better if the agent is slightly more simplistic so that it fits different ranges of children.

Overall, the most effective flow of an exercise explanation is 'talk, show, act', which first shortly explains the exercise. After that, the activity is illustrated with some visuals, by pictures or performance of the task. After that, the child will try the job himself. The visualisation of the exercise should use the body and including the used materials. It is also important to shortly name the exercise, its goal, the meaning and the effects of the activity. However, the talking should not take too long, and it is better to move to the visual explanation as soon as possible.

If the child does not wholly understand an exercise, they will do what they think is correct and choose the most comfortable way of performing the exercise. In these cases, it helps to explain the task again. This must always be done positively, and the misunderstanding should be bent back while not emphasising the mistake. Furthermore, there should always be a moment to ask questions so that the child has a moment to express his uncertainties.

Feedback

Overall, the feedback should be positive. For example, if the child should change something in his posture, the comment should not be like 'this should improve', but more like 'try it again in this new way'. So, if something should be improved, it is done by proposing a new way of doing the exercise. It is important always to use a positive approach and tell the child that he did a good job. Furthermore, the word 'not' should be avoided as much as possible. Often, children filter out the word 'not' and are not even hearing it. Therefore, it is more effective to show how something should be done instead of showing how something should *not* be done. Lastly, the spoken language of the feedback can be adapted to explain what is expected of the child—for example, talking a bit softer or louder when the intensity of the exercise is not correct yet.

Feedback can focus both on the performance of the child or the goal of the exercise. First of all, it can focus on giving feedback on the movements and performances of the child itself. Secondly, the feedback can focus on the goal of the exercise, which is called 'external feedback'. Participants stated that giving external feedback is more effective. The games from HoloMoves were seen as potential since they can use this external feedback and provide the user with feedback on whether something is achieved instead of whether a specific movement is done correctly. Game aspects, such as sounds and visual animations, can be used to give feedback after achieving a goal.

The timing of the feedback can be during the exercise or afterwards. This depends on the ability of the child to remember specific moments, and on the needed amount of stimulus to stay active. If the child needs a lot of support, it is better to provide him with a lot of feedback during the exercise. However, if the child has trouble to concentrate, it is better to wait with feedback until afterwards. Feedback can point out the exact moment when the child performed a movement correctly when given during the exercise. In this way, he can experience what is correct and when he is doing something right. Especially in rehabilitation, the child needs to build his trust in his body and experience different movements again. In these cases, it can be precious to give feedback during the exercise.

To make the agent apply to different types of children, the agent should provide some supportive comments during the exercise. However, this should be limited and not include explanations not to be too much. A lower frequency of feedback also helps to prevent feedback from losing its meaning.

Results of the agent-related questions

Participants found it important that the agent invites the child to join the game with enthusiasm and an outgoing introduction. Besides that, the agent should appeal to the imagination of the child, which can strongly differ among different children. However, a more general topic also works as long as it matches the level and popularity of the target group and can trigger the child. The agent mustn't look like a doctor of a therapist. Children already see a lot of doctors, and it can be refreshing to have a different character around.

Participants stated that one of the tasks of the agent is to explain medical information. They told the agent would be suitable to show this information, but the child and the agent should be on the same level. In this way, it will not harm or change the relationship between them. Furthermore, the agent should emphasise that the child and the agent are doing something together and together move forwards. For example, they are training together or are learning together.

The interviews also showed that the agent mustn't look too childish since children of the target age think of themselves as quite grownup and 'cool' and have shaped their ego. However, at the same time, the agent should explain exercises in an understandable and accessible manner, since they can be new and challenging to the child. Therefore, the agent should have a delicate balance between understandable and straightforward, but also not too childish.

The appearance of the agent

First of all, participants found that the agent should appeal to the imagination of the child, for example, by making it a more fantasy-rich creature or a human figure that doesn't look very realistic. Secondly, the child should be able to identify and connect with the agent. To achieve this, the agent should not be too childish or impersonal, and he should be taken seriously by the user. Different examples were named, such as a human figure, a comic hero, a robot, or an animal. Furthermore, the agent should either have an ageless appearance or look like he has the same age as the child. In this way, both younger and older children can feel a connection with the agent. Besides that, the agent should come across as friendly and open that invites the user to come and play. Therefore, his animation should be playful and energetic. However, he should also be fierce and not too childish. Next, the appearance of the agent should have a contrast with the surroundings so that it is easier to distinguish him from the background. Otherwise, it can be confusing and distracting to the child. The agent should not have too many colour differences.

Furthermore, participants did not see the gender of the agent as relevant, but the agent shouldn't look extremely boyish or girly to keep it interesting for all users. Besides, the voice of the agent should be very clear and understandable for all children. One of the participants stated the option that the child could choose the voice of the agent. In this way, there can be different voices that appeal to different children—for example, a male and a female voice, or a softer and a louder voice.

Feedback and communication

Generally looking, the agent should provide the user with feedback in a positive way. The feedback should be delivered both through sounds and visuals. Visual feedback could, for example, be done by showing positive emotions or through visual animated compliments, such as a high-five, a smile, or a thumbs up.

Next, communication with medical technology is often not very accurate in responding to the user. Therefore, it seemed better not to give the agent the ability to hear and understand speech and react to this. Children will realise fast that it is not possible to talk to the agent and they will accept this as logical. It will be even stranger if the agent responses on the child in a completely different and unexpected way. This will cause frustration, and the agent will lose its effectiveness. Instead of communication with speech, participants preferred the option where the user can select a premade answer by moving and clicking. In this way, the user is already moving his body.

Tasks of the agent

Overall, participants stated that the main goals of the agent should be providing an introduction, an explanation of the exercise, and feedback. The agent should furthermore have motivational and coaching elements, and he should be able to make and keep the user enthusiastic. Besides that, the agent should provide a bit of a challenge and stimulate the child to keep ongoing. Furthermore, the agent can keep track of how often a specific game or exercise is done. If needed, he can propose a different activity or ask the child if he wants to do something else. He can also suggest a break. Next, it could be motivational to the child if the child can play 'together' with the agent during a game. This creates a feeling of competition, but also of doing it together. If the child will play a game alone, the agent should not be visible in the screen or only for a short time to give some feedback. It could otherwise distract the child and have a negative effect. However, the feedback could also be provided through sounds while the agent is not visible in the screen. The child needs to recognise the voice as his buddy/agent. Before the game starts, the agent could count down or after the game has finished the agent can return to the game again to show some statistics. Last, it was stated by children that their therapy goals should stay out of the game. They already have enough doctors and therapists in their daily lives, and it would be better if they are free of obligations in the HoloMoves environment. Participants disliked it if the agent continually reminds the user of specific tasks that he should perform.

Roles of the agent

Most participants stated that the agent should have the role of a buddy. This role should be very motivational and refreshing since it can be stimulating for the child to do specific tasks together with the agent. It also matches better with the imaginational world of the child, and the small age difference would make it easier to identify with the agent. In this way, he can provide approachable comments or feedback. It is important that the information is told suggestively and not directive. Furthermore, the buddy-like agent should contain a form of humour in either his appearance or speech, where he should not come across as too childish.

The element of choice

The addition of choice was often used by therapists to motivate the children since it can have a strong psychological effect. If a child gets to choose between different options, he has the feeling that he has some input. Even if there only is a small selection of premade options, it can already

give the child the sense as if he has some control over the situation. This choice is always between two options that are both accepted by the therapists or expert. One of the therapists explained it as 'choosing between orange and red lemonade'.

Choices about the agent can give children the feeling that the agent is designed by themselves and makes it easier to identify with it. This can be very valuable and motivational to the children. Small things, such as changing the name of the agent or the skin colour, can already have this effect. It also works to give the child input on what will happen during the therapy session. For example, a choice on what exercise he will do, the game, the rules, or how often the task repeats itself.

2.5.3 Conclusions of the interviews

Conversations with the clients resulted in a more detailed view of the project and its structure. The client decided that the project will focus on young children, aged 12 till 16, that have to perform rehabilitation exercises. Furthermore, the agent should be a 3D character, feel like a buddy or a friend, and help the user to find their way together. He should aim to motivate, activate and provide information. He should be able to provide feedback and motivation and have the ability to guide and lead the user around and help to decrease feelings of isolation and loneliness for the children. The agent should implement small movements, such as nodding or blinking, to increase the liveliness.

Interviews with the experts resulted in more knowledge and understanding of the way therapy sessions work and how to do physical exercises with children. First, participants stated that it is important not to make the child feel like the activity is obligated to improve his motivation. Therefore, the therapists can discuss tasks with the child or let him make decisions to make the child feel independent. It also helps to make the child experience small successes to keep him motivated and adapt the level of the exercises to the level of the child. Therapists can further increase the motivation by explaining activities in a non-tradition way to make the child enthusiastic or intrigued. This could be, for example, by making it look like a game or an 'adventure'. Next, therapy goals can provide structure to the long- and short-term. Short term goals, for single therapy sessions, should always be achievable and match with the level of the child. Next, therapists explain exercises often visually and vocally to fit multiple learning types. The language used for this explanation should be clear and understandable, but not too childish. Exercises can use the 'talk, show, act' to explain it. Next, therapy sessions make use of feedback to stimulate the child and correct him. This feedback should focus on being positive, and the word *not* should be avoided. The feedback about the completed exercise can focus on the goal of the activity (external feedback) or the performance of the child. Feedback given during the task should be limited to supportive comments to stimulate the child but not be too distracting.

The interviews with the experts and children resulted in more insight into the desired concept of an agent. First, the agent should appeal to the imagination of the child, and the child should be able to identify and connect with him. Therefore, the agent shouldn't be too childish. Next, the agent should come across as friendly, open, inviting, and playful, and his appearance and voice should be clear and understandable. Next, the agent should provide the user with feedback in a positive way, and he should combine both visual and vocal feedback. Visual animations can emphasise certain things, such as a high-five or a thumbs up. Next, the communication should be smooth and understandable. To achieve this, a participant stated the option where the child only communicates through multiple-choice options. Next, the main tasks of the agent are to introduce, explain, motivate and provide feedback. He should stimulate the child and give a bit of a challenge. The agent and the child could also play or work together to increase the 'buddy' like

feeling. This means that he should be very motivational and stimulating to the child, and he should use humour in his appearance and speech.

4. Lo-Fi evaluations

This section reviews the information from the related work with the experts and children during an evaluation. This project developed the concept of Design Cards to assist the assessments. This section will first explain the idea of the Design Cards. After that, it will continue with the evaluations of the cards with the experts and children. The evaluations mainly focus on the shape and the embodiment of the agent.

4.1 The Design Cards

The research of related work resulted in a detailed table with many different categories and aspects, as described in the previous chapter. However, the large amount of data made it hard to understand each agent fully and compare them to each other. The table further made it harder to analyse all the agents visually. This was especially a problem since this research focusses on children. It is possible that the format of the table would appeal less to them and would not invite the children to engage in the evaluations.

Therefore, the project aimed to display information from the related work table in a more visual way. Existing card games that use visuals offered inspiration for this, such as, for example, the Pokemon cards or a quartet card game (Figure 26). These cards often contain a name, a picture and some specific features, such as shown in Figure 27.

Figure 26: An example of a Pokemon card, source: pokemon.com

Figure 27: An example of the Design cards developed during this project

This idea could also apply to each of the agents from the related work table. Each card contains the name of the agent, a picture and specific information about the researched aspects (Figure 27) The specifics of each agent include the following different elements: goal, target group, dimension, shape, movement, gestures, body, on-screen time, style, communication input, Behaviour Change Technique, facial expressions, feedback, voice, and feedback delivering style.

Each card summarizes the specific information for each agent in a few keywords. The extracted information from the table resulted in an overview of 24 design cards (figure 28)

Figure 28: The set of Design Cards

4.1.1 Iteration on the Design Cards

The first set of Design Cards, as shown in Figure 28, was discussed with the stakeholder. This validated the method of using cards and their layout. The stakeholder was enthusiastic about the technique but noted that the way of presenting the cards was too overwhelming. There was no underlying structure which made it feel like there were too many options to choose from. The client proposed that different categories could help to create structure and visualise the different types of agents. They further found the robotic class to be promising but would like to see a larger variety of shapes.

The feedback from the client was taken into account and resulted in an updated version of the Design Cards. First of all, the overview grouped the different agents into four sections: humans, animals, robots and animals. This reduced the overwhelming effect of the agents and allowed participants to break down the selection more quickly. It also allows for layering questions during interviews and steering the conversation. An interview can, for example, start by discussing the different categories and continue with the individual characters from each group. Secondly, the updated version removed agents that looked strongly the same, so each category only included original shapes. The third modification extended the robotic category with more agents to show a larger variety of shapes. Last, the updated version added more colours to improve the clarity of the structure.

The alterations led to the updated version of the Design Card overview, as shown in Figure 29.

Figure 29: The updated Design Card

4.1.2 Advantages and Disadvantages

The Design Cards can be valuable during interviews and conversations with the client and participants of a study. However, the card technique could also have adverse effects. The next sub-chapter discusses both the advantages and disadvantages.

<u>Advantages of the card method:</u>

- The concept where a card visually displays key-points, like the Design Card system, is a commonly used technique, for example, for pokemon cards or a quartet game. Since both children and grownups are (often) familiar with these concepts, it makes it easy to understand the purpose of the Design Cards. This allows the technique to introduce new ideas or topics easily.
- The data from the research is visually displayed so that participants can absorb it easily.
- The Design Cards contain all the essential information and show this in a summarized and to-the-point way. Therefore, participants do not have to read a research report and do not need much background information.
- The cards show all the available information simply. This makes that everyone can understand the presented information, and this creates a common ground which allows researchers and participants to talk about it together.
- The Design Card system guides interviews or conversations, by focussing on different categories or a selection of cards.
- The card method uses two layers: four primary categories, and the individual cards. This makes the overview less overwhelming since the categorisation makes it easier to break down the selection. Besides that, it makes it easier to chose individual cards because participants can first look at the different categories and continue by looking at the single characters from each group.
- Differences among the designs can be better spotted since the cards make a compact overview instead of a table.

- The cards can be physically touched, moved around, sorted, and categorised by the user. This creates more interaction with the cards and the information on them.

Disadvantages of the card method:

- The cards show the visual image, which disables the participants to visualise a concept or use their interpretation freely.
- The overview gives participants a set of fixed options to chose from, which could result that they might not think about alternatives anymore.
- Individual category names could appeal more to the participants, which can make them focus on a direction before they are entirely sure of that choice.
- The Card System only uses one picture of each agent, which could be misleading to the participants. This picture doesn't fully represent the agent since it cannot visually show the movements, his way of communicating or the ease of interaction. Furthermore, the same agent can look different in multiple images and provoke different feelings on each of them, which could influence the evaluation of the participants depending on the used picture.

4.2 The evaluation

4.2.1 Goal

This evaluation aims to discuss the Design Cards with experts and children. The evaluation focusses mainly on the embodiment of the agent, and the outcome will show the first preferences of the users. This information provides a starting point for the ideation phase.

4.2.2 Participants

The participants in this evaluation are the same participants from the earlier described interviews. Both the interviews and the evaluations took place during one combined session with the participant. However, the report divided this into multiple segments for the ease of understanding the design process.

4.2.3 Methods

The evaluation started by showing the participants the Design Card overview and briefly explaining the concept. After that, the participants had some time to absorb the displayed information.

The evaluation continued with a semi-structured interview to gain insights into the preferences of the users. A total of five questions served as a guideline for the interview. Each question asked the participant about their top three. The interview used the following questions:

1. Which three agents appeal to you the most?
2. Which three agents appeal to you the least?
3. Which three agents are most suitable to explain things to a child?
4. Which three agents are the best at being a playing buddy?
5. Which three agents feel the most trustworthy?

4.2.4 Setup

A skype call provided the connection between the participant and the researcher. The screen share function allowed the researcher to share a picture of the Design Card overview with the participants. In this way, they could see this picture on their screen while still maintaining contact.

4.2.5 Results

Stakeholder evaluation

The stakeholder liked the robotic category the most, mostly because of the simplistic and stylised shapes. The client liked the robot 'Lena' the best since her form is simple, but she has arms, legs, and a face to communicate. Furthermore, the stakeholder liked the creative freedom that a robotic shape would give the designer since a robotic shape could easily transform into different forms to fit different situations. A robot could turn into a drone, where he can fly in and out of the screen, while still maintaining his appearances and recognisability. Robotic shapes, such as Eve [17] and HAL [18], were named as possible other shapes. Eve (figure 30) looks simplistic but effective in her appearance. Her form allows for different modifications, such as the addition of hands, feet or wings. Besides that, her face has just enough elements so that she can show emotion. The stakeholder also named HAL (figure 31) as an example as a famous robotic character. The robot has a personality and can convey emotions. However, the shape of the robot was found less useful, since it has a static appearance. Besides that, HAL does not have a face and therefore misses a communication tool.

Figure 30: EVE from the movie Wall-E, source: pixar.fandom.com

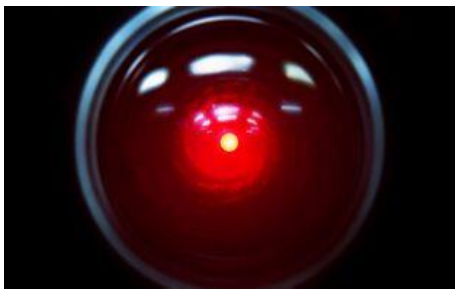


Figure 31: HAL from the Movie Space Odyssey, source: 2001.fandom.com

The stakeholder liked the other categories less. Duolingo and Echoes were too childish for the target group, according to the stakeholder. Others, such as Eliza, Greta and Alice, were found to be too detailed and grownup. Furthermore, the client prefered agents that are modelled in 3D, since the company also makes 3D games.

Expert and children evaluation

The evaluation started by asking the participants which category they would prefer. The table in

[17] https://pixar.fandom.com/wiki/EVE
[18] https://2001.fandom.com/wiki/HAL_9000

Table 1, visualises how often participants consciously evaluated the categories as positive (green) and negative (red) during the interviews.

Overall, the robot category scored the best, followed by the human group. Both experts and children agreed on this. Main arguments for this were that the ability to form a relationship and perform physical exercises is more natural with a human or robotic shape. The robotic category provoked positive remarks such as a funny appearance, a trustworthy feeling, playful, not too serious in appearance, and suitable to show an exercise and explain. The human category scored best when the character looks happy and motivational. However, the participants noted that this category tends to look fake and that strict and teacherlike agents were not preferred

Participants evaluated the objects and animal category less. Objects and abstract shapes would make it harder to allow a connection between the user and the character.

Table 1: The evaluation of categories

Next of all, the evaluation continued by looking at the individual agents (Table2). The next section discusses the results of the experts and children. The numbers represent the different agents, as shown in the picture of Figure 29.

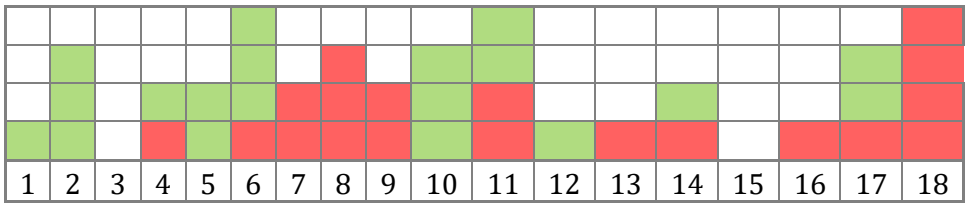


Table 2: The evaluation of the individual robots

Experts

Experts often liked agents two and ten and saw them as effective. Reasons were their potential to be a playing buddy, the animation style, their human-like body shape and their playful appearance. However, agent two was a little bit childish, and agent ten looked too much like a teenager with a careless appearance. However, one of the participants proposed a combination of two, five and ten to make a more fitting character.

Furthermore, the participants liked the animation style of the agents ten, eleven and twelve. They further liked agent twelve for his neutral and buddy-like appearance and the fact that he is visible from top till bottom. However, this agent felt a bit stiff. Furthermore, participants evaluated agent six as funny and neutral but slightly childish.

Other agents were evaluated negatively, such as agents seven, eight and nine. Those agents were seen as strict, flat, 'unreal' and not motivational or happy. Agent eleven was also seen as too old,

which would be less fitting to the target group of younger children. Furthermore, the participants thought that agents seventeen and eighteen looked too childish to appeal to the target group. Besides that, animalistic shapes with a non-human body, such as agent sixteen, were seen as ineffective since it would make it hard and confusing to explain physical exercises.

Last, there were some general remarks made by the experts. They stated that the agent should have an open face with a mouth that allows for open communication. Furthermore, the attitude of the agent should be interested, happy and open. The agent should also have a clean and simplistic appearance.

Children

Overall, the children evaluated the agents five and six positive most often. They looked funny, clean and simplistic, and not too childish. The participants assessed the following agents also positively: two, ten, eleven and seventeen. Agent seventeen had a funny and energetic appealing aspect, and agent eleven looked trustable because of his older ages. Agents two and ten seemed to be a good playing buddy because of the peer-like looks (ten) and the inviting and open appearance (two). Children furthermore found that agent two had a vibrant, but childish appearance. One of the participants noted that his style allows for small additional elements, such as dungarees or a straw hat, to make him fit the context.

The participants evaluated other agents more negatively. Agent one and four looked too mechanical and impersonal, and the bodybuilder appearance was mismatching with the children. Children disliked the humanlike agents seven, eight and nine since they were not appealing and had too little fantasy in their looks. Furthermore, they were only visible with their upper body which makes it harder to be a playing buddy. Last, agent thirteen looked unreliable and unfitting to explain information, and agent eighteen seemed irritating to the children.

The participants made some other remarks about the agent. They stated that the agent should have a simple, happy and relaxing vibe. Besides that, the agent should invite the user to join and convince him that they will perform activities together and that the agent will not disappear after explaining the task. They further stated that the art style should have a mixture of realism and fantasy. Children also reported that agents should not resemble an existing shape too much since it can be associated with the wrong things.

4.2.6 Conclusions

Both the stakeholder, the experts and the children preferred the robotic category over the other three. The participants saw the shapes in this category as simplistic, funny, trustworthy, playful and not too serious. They also noted that it is easier to form a bond with a robotic or a humanlike shape.

The evaluation also resulted in a couple of requirements that the agent should fulfil. Both the stakeholder, the experts and the children stated that the agent should not be too childish. A combination of the agents two, five and ten were proposed as suitable to the target group. Furthermore, the character should combine text and speech, but the voice should be ordinary and matching with the appearance so that it is not distracting.

The attitude of the agent should be motivational, energetic and relaxing. Participants further described it as interested, happy, open, funny, personal, trustable, welcoming and inviting.

The shape of the agent should be clear and self-explanatory so that the user doesn't have to think about what he is seeing. Besides that, the agent should look like a peer so that he can be a fitting playing buddy. His body should contain human-like aspects and be visible from top till bottom so that he can explain physical exercises with this. His shape should furthermore remain clean and straightforward, and he should not look like a human too much. The agent should have a face so that he can show emotions and personality. Last, the shape should be rich in fantasy and imaginative, so that the child can use its imagination.

5. Requirements

The literature research, related work, interviews and card evaluations proposed many possible aspects or design choices that this project could consider. However, this is a large variety of conditions and options, and it is not possible to implement all of them into one agent. Besides that, some aspects describe multiple possibilities, where only one of them can be applied.

The section below describes these foundings, based on their origin of the literature research, the client, the interviews and the card evaluations. They are not requirements, but they shape the design space of the project and give a broad overview of all the possibilities.

After this broad list of possibilities, this chapter continues with a more specific list of requirements. Those items resulted from the evaluations with the client and the experts and are directly accurate to this project.

5.1 Potential design guidelines

The research outcomes let to many aspects that this project could consider or that occurred often. This information is not strictly required but can guide and steer the design process. Therefore, this project can view them as useful and potential input.

<u>Guidelines from literature research</u>

- Some behaviour techniques that often appeared are goal setting, showing information, keeping track of personal objectives and achievements, rewarding, praises, reminders and motivational messages and path revealing.
- The social relationship between the agent and the user can develop over time to improve the realism of the agent. The behaviour of the agent could also depend on the input from the user to increases this realism. Besides that, the agent could use a pausing model in his behaviour, to simulate him thinking or typing.
- The agent can use different communication and feedback tools. Facial tools that occurred are the gaze, blinking, facial expressions, head nods or tilts, and mouth movements. Body tools are shifts in posture, gestures, arms. These body and facial elements can steer the attention of the user into different directions. The agent can communicate information through speech or written text. The communication should feel natural, and the agent should seem to understand the user.
- The functions of an agent used for children is often a peer-like coach or a buddy.
- The attitude of the agent can include humour and empathy. The agent can have his own personality by adding character traits and personal stories, which also increases the human-feeling.

- The appearance of the agent for children uses enlarged head, eyes, arms and hands. This strengthens communication. The shape should be engaging and interesting and not too general.
- The shape of the agent can either be very detailed and realistic or only simply show the essential shapes, excluding extra details. These simple shapes often focus on aesthetics and a consistent colour scheme. The agent itself doesn't have to be always visible but can change to a smaller icon when he is not needed.
- The agent can use random animations to increase the liveliness of his appearance. These random animations were often 'funny', such as showing a dance or a high five. He could also use continues movements, such as blinking, breathing, hair movements, to increase this.
- The digital environment of the game could use a storyline where the agent matches with this context. The agent could give the user small tasks or goals that also fit this story.
- A game for the HoloLens can use the space around the user to implement interaction elements, such as arrows or signs.

<u>Guidelines from related work</u>

- An agent for children often looks like a cartoonish and animated young boy or an animal, and he usually has the function of being a coach or an adviser.
- The agent often sues motion, gestures, and both his arms and hands.
- When the digital environment is in 3D, the agent is also in the 3D dimension.
- Communication between the user and the agents often uses buttons or multiple-choice options.
- Agents often use behaviour change techniques, such as goal setting, information display, awards, praises, reminders, path revealing, feedback, advise, instruction or hints.

<u>Guidelines from the client</u>

- The agent focusses on young children, aged from 12 till 16
- The agent should be a 3D character, feel like a buddy or a friend, and help the user to find their way together.
- The agent should implement small movements, such as nodding or blinking, to increase the liveliness
- The agent should aim to motivate, activate and provide information. He should be able to provide feedback and motivation and have the ability to guide and lead the user around.
- The agent should help to decrease the feelings of isolation and loneliness for the children

<u>Guidelines from interviews</u>

- The child shouldn't feel forced to do an activity. Therefore, the agent should not give a strict feeling, but should discuss things with the child and give him input.
- The agent should give some independence to the child by letting him perform the exercise or giving him a choice.
- The therapy should match the level of the child to motivate and let them experience success.
- The environment and the agent should speak to the imagination of the child

- The agent should use humour in the conversation to make the child enthusiastic and intrigued, which take the focus away from the therapy.
- Rewards or punishments can be motivating
- The agent should include therapy or session goals to structure the activity. Those goals should always be achievable
- The agent should combine visuals and vocals to use multiple learning entrances of the child
- The language of the agent should not be too childish, but easy understandable for all levels
- The agent should fit children with different levels, and therefore should be more simplistic
- The explanation should be explained, showed and then performed by the agent.
- The agent should approach mistakes from the child in a positive way.
- Feedback should be given in a positive way, and the word *not* should be avoided
- The agent should aim to give external feedback
- Feedback should be given mostly after the exercise to let the child concentrate. But the agent should make small, supportive comments during the exercise to provide stimulation.
- the agent needs to invite the child to participate in the game
- the agent should provoke the feeling that child and agent do things together
- the agent should not look too childish in order to match with the target group
- come across as friendly, open, inviting, and playful.
- the agent should be a buddy
- the communication should be smooth and clear, therefore, multiple choice can be used
- main tasks are: introducing, explaining, motivating and providing feedback
- should use humour in his appearance and speech
- the agent could use choice to give the child the feeling of input and control

<u>Guidelines from the card evaluations</u>

- The robot category is the preferred category
- The user should be able to bond with the agent
- The agent shouldn't be too childish
- The agent should combine text and speech
- The attitude should be motivational, energetic, relaxing, interested, happy, open, funny, personal, trustable, welcoming and inviting
- The shape of the agent needs to be self-explanatory
- The agent should be a 'buddy' to the user
- The shape of the agent should be visible from top till bottom and contain human-like aspects to explain exercises
- The agent needs to have a face to show information and emotion
- The shape of the agent needs to be fantasy rich and imaginative

5.2 Design requirements

The following requirements were evaluated as necessary or required by experts and the stakeholder. Therefore, they are requirements that the agent should fulfil. The requirements split between the features of the agent and the functions of the agent.

The features of the agent

- The agent should have a robotic appearance
- The agent should not be childish or impersonal but understandable and straightforward.
- Appearance should have a contrast with surroundings, for easy distinguishing him from the background, but he should have not too many different colours.
- The agent should apply to both girls and boys, so no extreme girlish or boyish looks.
- The agent should have a lot of humour and non-traditional/funny animations.
- The imaginary world of the kid is important. The agent should connect with this.

The functions of the agent

- Feedback positive and encouragements. External feedback used afterwards and supportive comments during the exercise.
- The agent should be enthusiastic, outgoing, trustworthy, open, friendly, playful, energetic
- Tasks are: activating, motivating, and providing information
- The agent should explain information in such a way that child and agent are on the same level and are doing things together
- The agent should explain the exercise both visually and verbally
- The explanation should be understandable for different levels of children
- The explanation should use the 'talk, show, act' pattern of exercise explanation
- The child should feel free to make choices and decisions on his own
- The agent should allow for fast successes to motivate the child
- The agent should praise and reward the child after successes
- Feedback should be delivered positively through both sounds and visuals.
- The communication with the agent should go through speech and visuals from the agent's side, and the choice of different options from the user side.
- The therapy goals should stay out of the game, except for in-game purposes.
- The agent should have the feeling of a buddy.

6. Ideation

This ideation will describe the design process of the embodiment of the agent and will result in three concepts. It will start by describing the starting point of the process by looking at the initial requirements. Then, it will research how those requirements can fit into a design and result in a list of practical and implementable aspects. Next, these elements will provide input for the sketching phase. During this phase, design choices guide the process where the design slowly develops until it reaches the final concept. These choices base itself on the reason and judgment of the researcher. Next, a selection of the ideas is made together with the stakeholder. Last, three final concepts are researched further, by looking at the form specific behaviour of the induvial shapes. This will result in the embodiment of three agents, including their unique behaviour.

6.1 The starting point

The context analysis concluded with several requirements to implement regarding his features. First of all, research showed that the agent should perform the tasks of introducing the world, providing information, and motivate the child to move. Besides that, the Design Cards showed a clear preference for robotic figures. Some of the prefered robots were humanoids with a more 'traditional' robotic feeling. Other robots looked more modern, simplistic and stylized. Experts showed a preference for more humanlike characters with a robotic feeling because human features can be better used to explain therapeutic aspects. Therefore, the ideation will use the starting point of humanoids.

Besides that, the evaluation showed that the agent should radiate feelings of friendliness, simplicity, mobility, enthusiasm, and playfulness. The design of the agent should fit with those elements and use them as a guide during the ideation process. Furthermore, the context analysis showed that a fantasy rich, robotic creature was preferred, but that he should have a clear face with human characteristics such as eyes and a mouth.

Altogether, the ideation phase started with the concept of an agent that has the tasks of introducing, and providing information and motivation, with a robotic body with human-like aspects, that needs to look friendly, enthusiastic, playful, energetic and simple.

6.2 Exploring the shape

The main requirement of the appearance is to provoke feelings of friendliness, simplicity, mobility, enthusiasm, and playfulness. At the same time, the design should be fitting to the age of the target group, which has the challenge that the design should not be too childish.

Inspiration was taken from the robots from 'the Robot Facebook' by Edwin Dertien, to research specific elements that contribute to those feelings.[19] Especially the category 'Cartoonish' was a source of input since earlier research on related work showed that most agents fitted into this category. The robots from the 'Robot Facebook' were analysed to distinguish the different elements that make a robot radiate the above feelings. The exploration of the shape bases its information on comparisons between multiple designs and the view of the researcher, but it uses no scientific groundings from literature.

The main findings of the analysation show that often the head, eyes and body of the agent are adapted to create different feelings. The overall results are visible in the sketch from Figure 31.

[19] http://robotfacebook.edwindertien.nl/product-category/cartoonish/

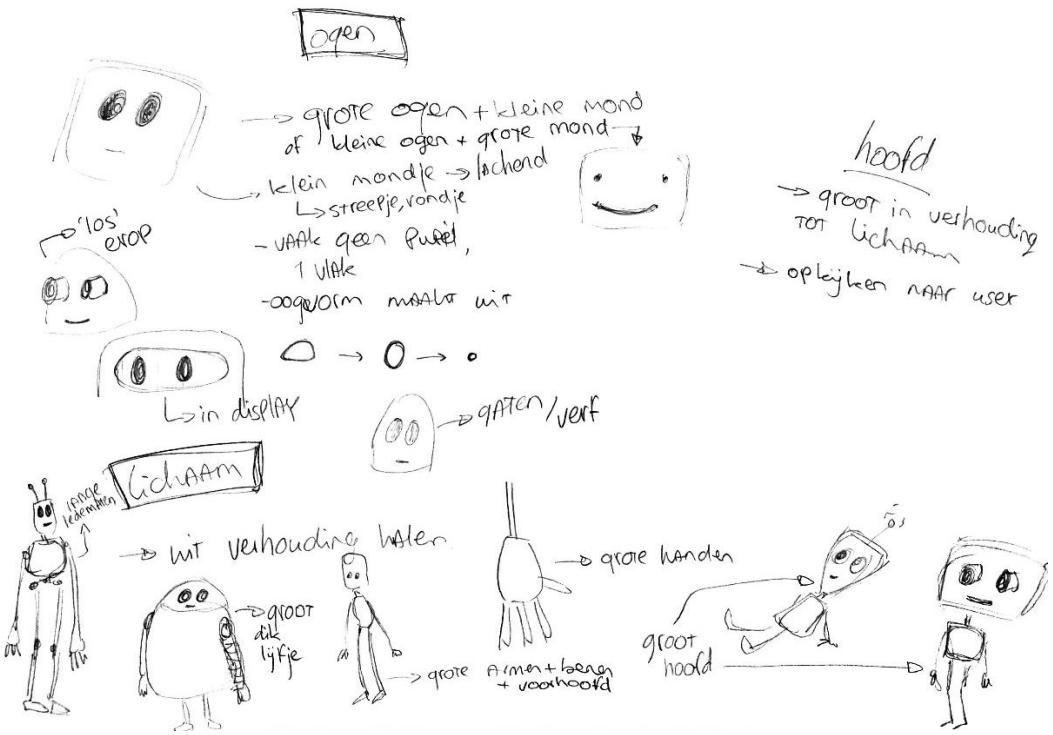


Figure 32: Analysation of the robotic aspects

The eyes are a substantial factor in making the agent look friendly and trustable. Often the eyes are big and shaped oval or circular. Big eyes often go together with a small mouth in a thin line stroke, where the corners are pointing upwards. A second possibility is that the eyes are relatively small and circular. In these cases, the mouth is often a big and stretched thin line. The eyes are often shaped and flattened in multiple ways to show different emotions.

Secondly, a robot often has body elements that are out of proportion. This could be, for example, extra-long limbs, a fat 'barrel' body, big hands or feet. However, the combination that occurs most often is a large head in conjunction with a smaller frame.

6.3 The sketching process

The analysation of 'the Robot Facebook' resulted in specific elements that serve as input for the sketching process. First, some explorational sketches of the head where made (Figure 33). The requirement that the head of the agent has to look more humanlike was taken into account here. The decision was made to use more cylindrical and vertical shapes over horizontal shapes since this resembles more with the human head. Furthermore, a shape with humanlike proportions seemed most appropriate when looking at the requirements.

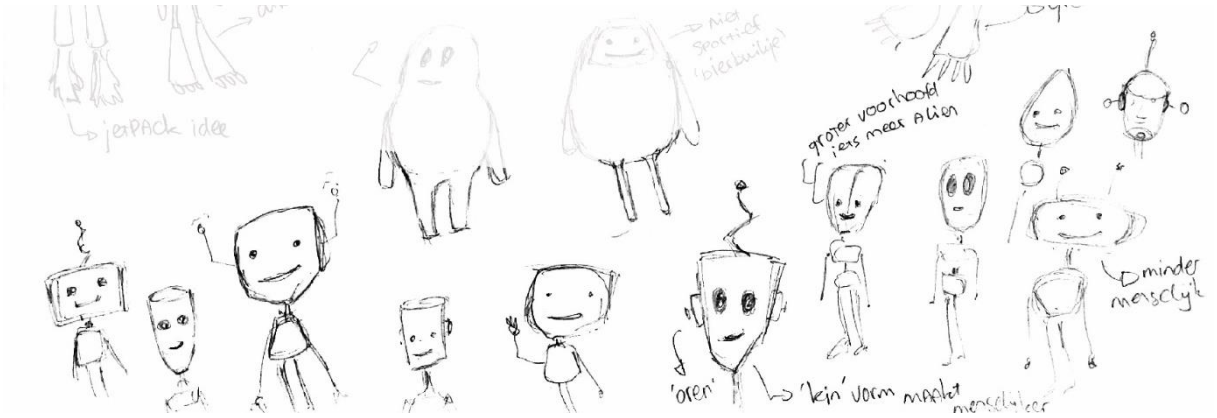


Figure 33: Sketches of robotic heads

The next step explored the idea of taking body parts out of proportion more (Figure 34). The first few sketches examined the possibility of lengthening the arms and the legs. The sketches showed that the combination of long arms with big hands that reach almost until the feet gave a bulky and slow feeling. However, in combination with long legs, the long arms gave a much more energetic atmosphere.

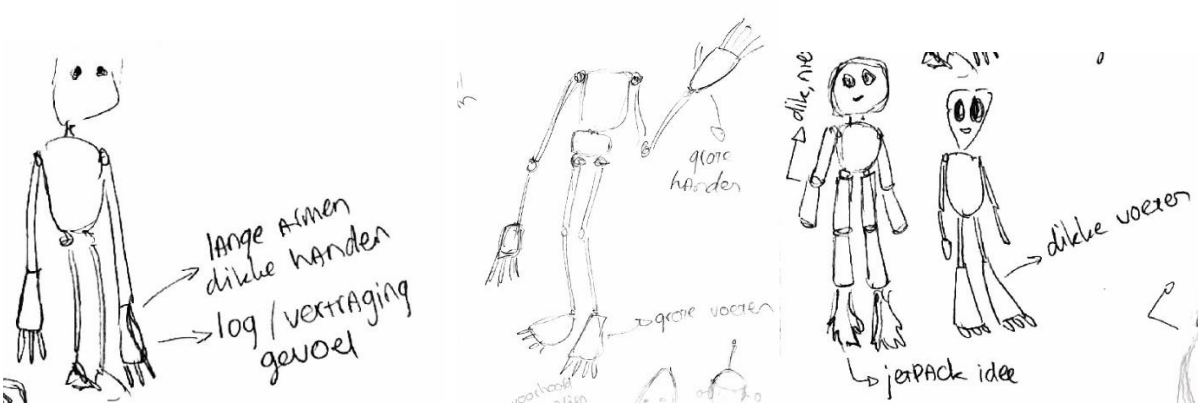


Figure 34: Sketches of the limb proportions

The next step developed the enlargement of hands into more robotic shapes (Figure 35). This created a less humanlike feeling. Furthermore, the shape of the arms and legs can be cylindrical and have the same width over the whole length of the shape, or they can be more triangular. The cylindrical shape gives the idea of a more 'mechanical' robot shaped out of industrial parts. The triangular-shaped arms and legs provided a more sophisticated feeling due to the differences in diameter over the length of the limbs. Robots that have thin upper arms and legs in combination with flared lower arms and legs, create the feeling that the figure is wearing mechanical 'cloves' or 'shoes'. This adds to the sense of a non-humanlike body.

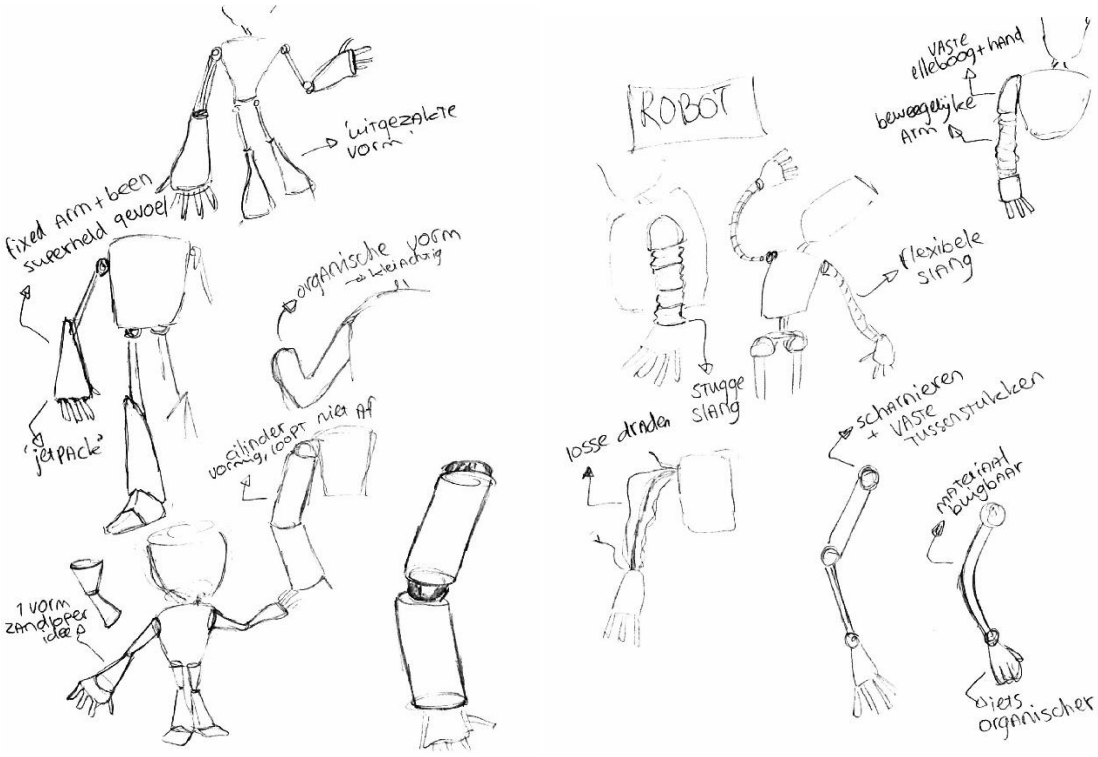


Figure 35: Sketches of robotic limbs

Next, one of the requirements from the context analysis was that the robot should be playful, energetic and mobile/sporty. Therefore, the sketches focused on showing these aspects through the layout of the arms and legs (Figure 36). Arms that have joints and solid pieces give a more stiff and motionless feeling. However, arms made out of flexible tubes have a much more mobile feeling. Furthermore, the figure can be made less rigid by removing the cubical shapes into more rounded shapes.

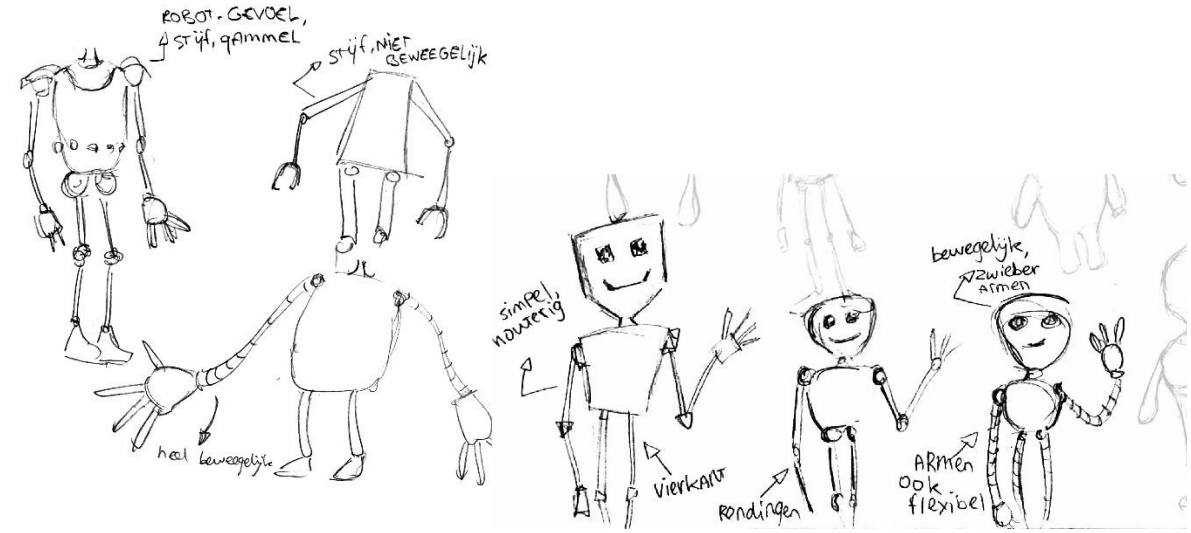


Figure 36: Sketches of mechanical and organical arms

Next up, different robotic aspects where explored (Figure 37). The earlier exploration session found that robotic figures often have something on their head, like an antenna or an energy output. Besides that, robotic characters often have different ways of transporting, where human figures are usually limited to their limbs, and it is seen as less usual if elements like wheels or

springs appear. However, since robots are mechanical and made out of different parts, they allow for additional components. Therefore, transportation elements, such as a jetpack, fire or propellers, can be used as additional features of the robot.

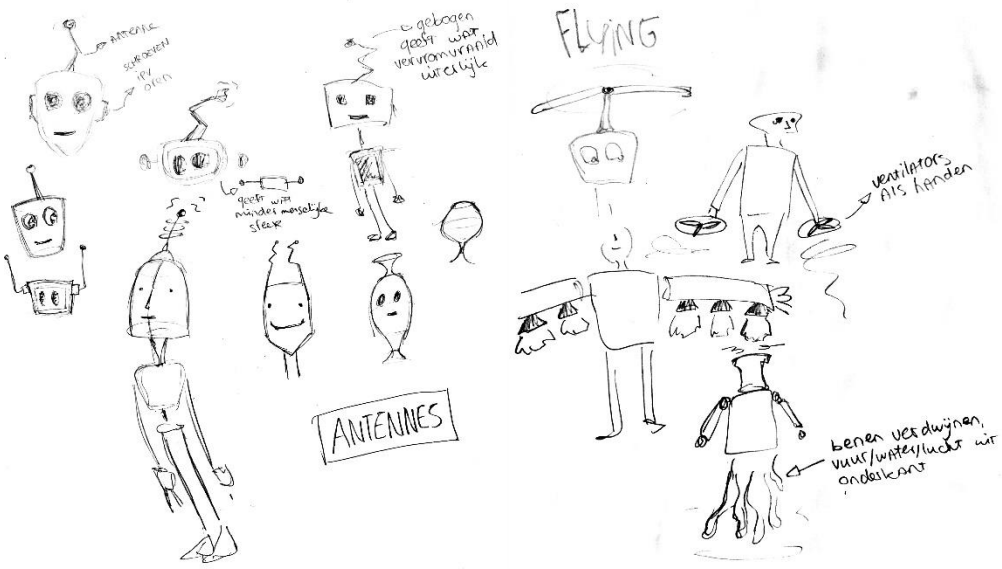


Figure 37: Sketches of transportation elements

Up until now, the robots looked mainly mechanical, and the sketches looked at 'traditional' robots. However, earlier evaluations with existing agents showed positive responses to more modern and simplistic robots. Therefore, the 'mechanical' robotic shapes intertwined with more organic and simplistic shapes (Figure 38). Sketches showed that thicker bodies with rounded bellies give a less sporty appearance. However, they provide a simplistic, cuddly and 'soft-hearted' feeling. The drawings furthermore showed that rounded bellies in combination with shorter legs give a less sporty sense, where smaller bellies with the same legs provide a much more energetic feeling.

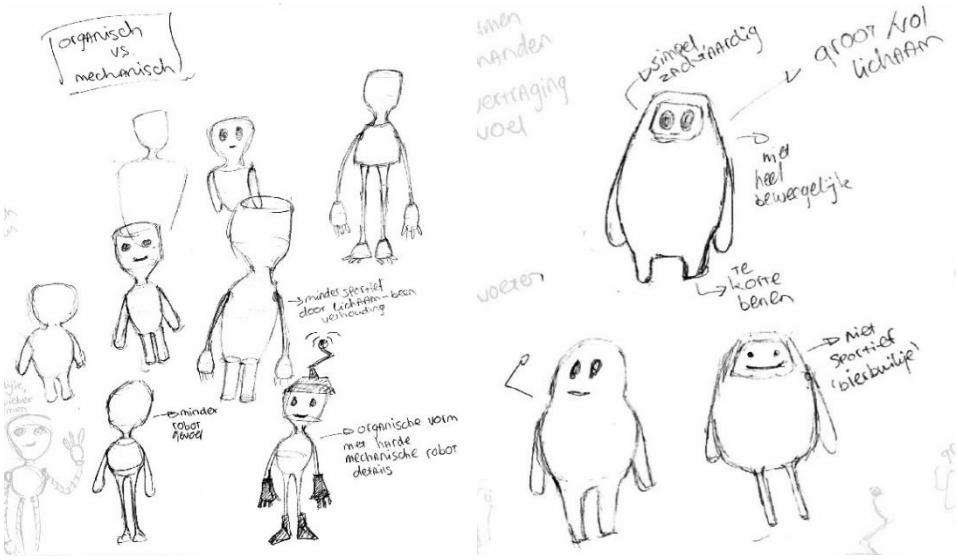


Figure 38: Sketches of organic robotic shapes

Next, the earlier described idea of having out of proportional body parts combined the organic and simplistic look (Figure 39). Instead of 'loose hand parts', the hands are one shape with the rest of the body. This created the feeling that the robot can grow and evolve because of its organic material.

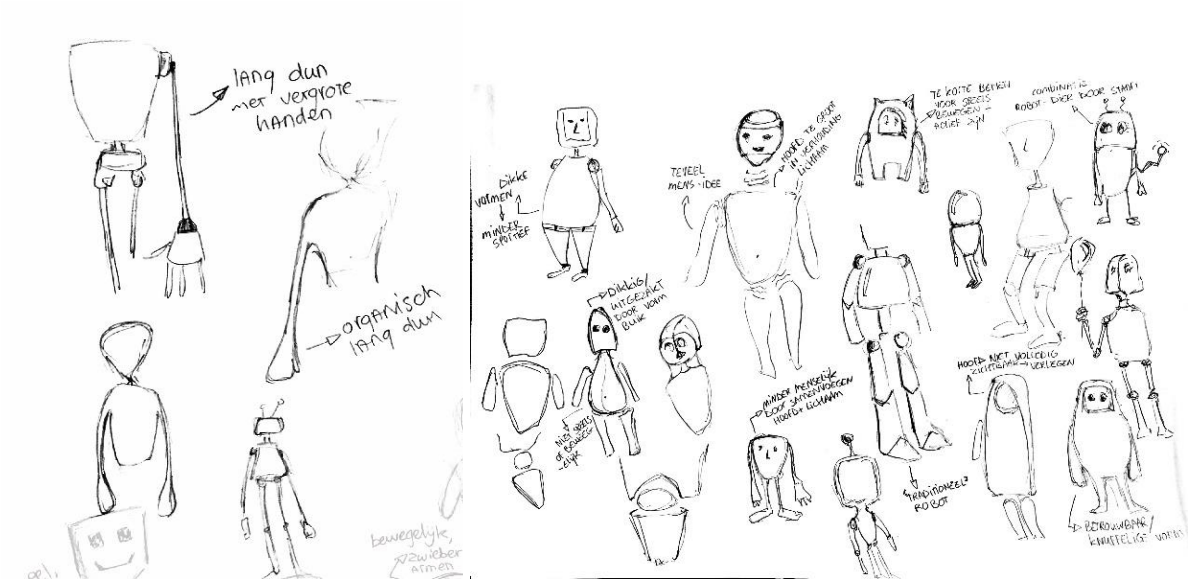


Figure 39: Sketches of simplistic and organic shapes combined

The organic shape further developed into a more animalistic shape (Figure 40). However, earlier evaluations showed that participants preferred robots and humans over animals. Therefore, the sketches used the animalistic concept to create characters that look less like an animal and more like a robot. The resulting shapes looked less like existing shapes and looked more like imaginative creates than the sketches before.

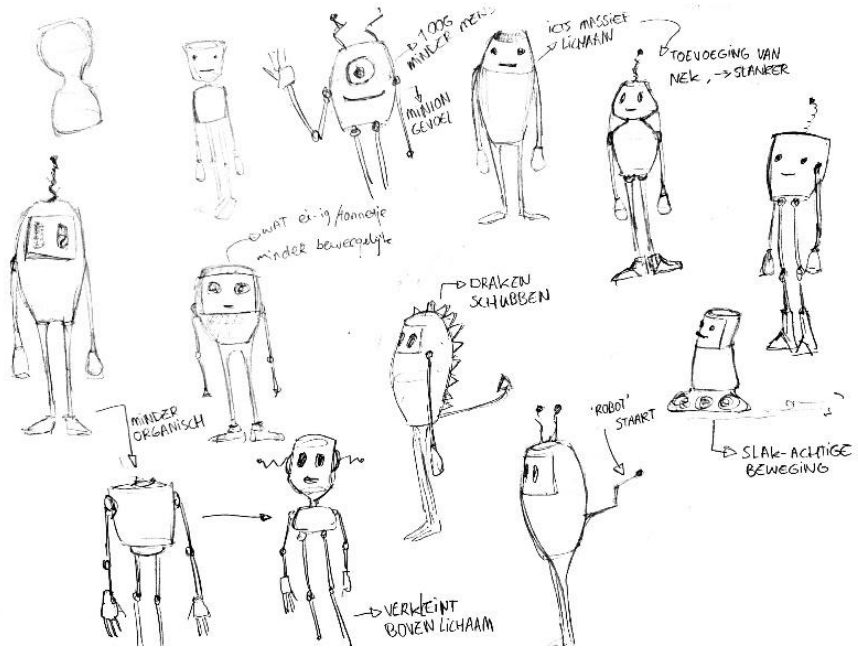


Figure 40: Sketches of the animalistic robotic shape

The animalistic robot concept further developed were more robotic elements slowly replaced the animal aspects (Figure 41). A surprising finding was the addition of a cartoonish mouth in the animal shape. This provoked a friendlier vibe and made the character look more communicative. The addition of a mouth also gave him a friendlier and more open feeling.

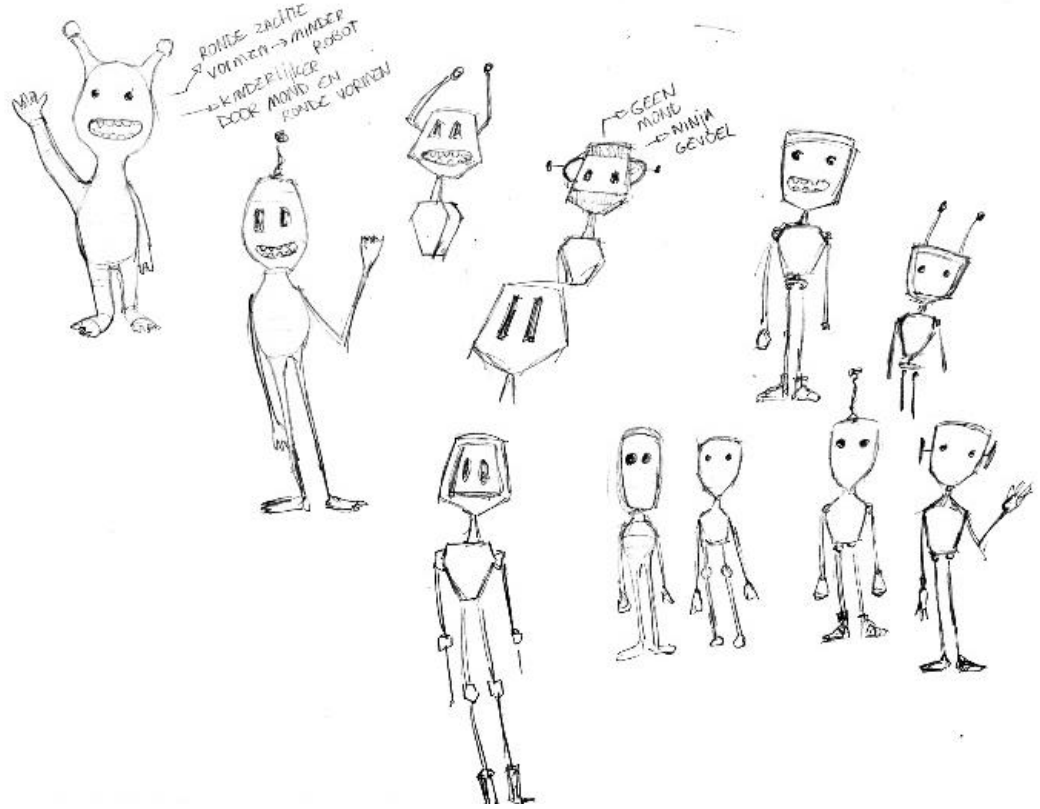


Figure 41: Iterations on the animalistic robotic shape

Next, sketches tried out different transportation methods with their effects on appearance (Figure 42). An antenna could have different functions, such as letting the agent fly or show emotions or directions. A modern and simplistic shape could use a propeller to fly or move around. This idea applied to simplistic robots and more human-like robots.

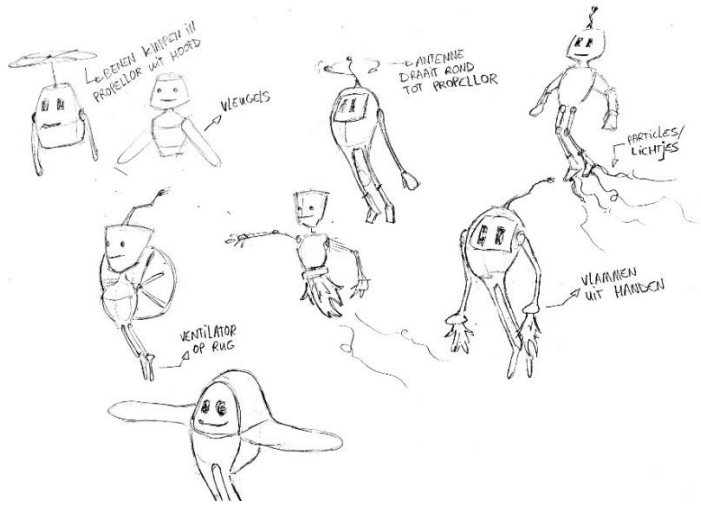


Figure 42: Sketches on the robotic shape in combinations with different transportation methods

Next, the sketches tried out the concept of implementing a 'life source' to the agent (Figure 43). Therefore, the idea developed to create the feeling of a fire or an energetic source. The agent could show this in his belly, head or antenna. This idea also gives the possibility of letting the agent appear and disappear by showing this 'life source' as particles. The particles could represent the agent when he is not completely visible with his body.

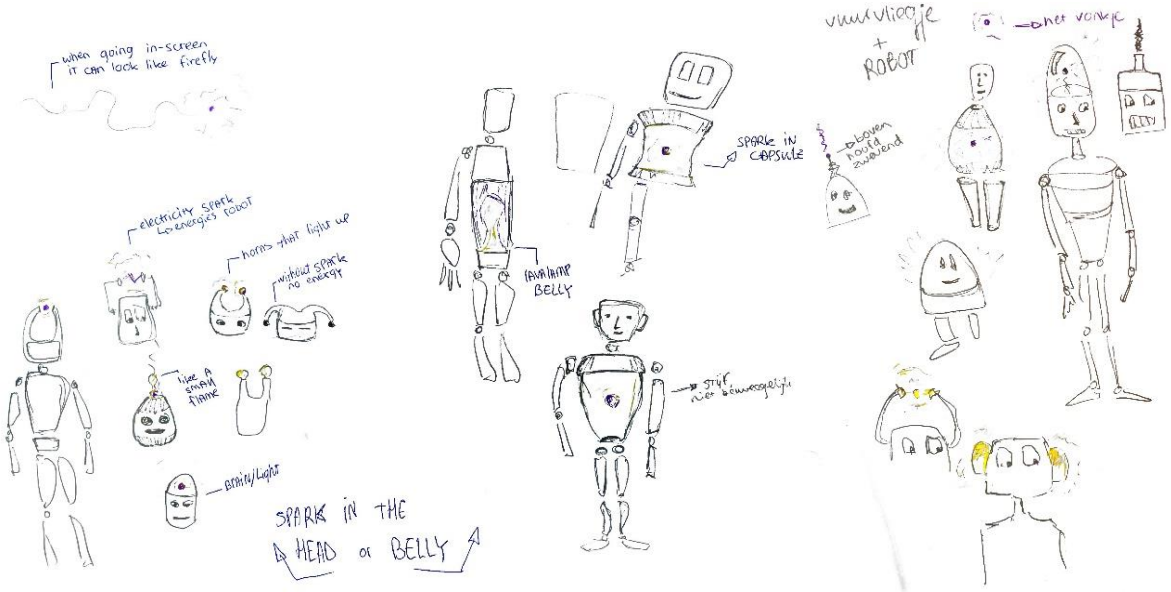


Figure 43: Sketches on the 'life source' concept

6.4 Selection of the concepts

The next step of the ideation phase presented the different sketches and concepts to the stakeholder, as shown in Figure 44. This has the goal of making a selection of the various drawings so that the design process can continue with a smaller amount of ideas. The following section describes the main arguments of the stakeholder and the resulting concept choices.

The stakeholder stated that mouth and eyes are essential elements of the robot. They allow for communication and can show different types of emotions. This was the first criteria for the concepts since the sketches should include a clear face with eyes and a mouth. Secondly, the client stated that the agent should be able to perform essential tasks of activating the child to move, providing information, and motivating him to perform exercises. The client also stated that the agent should be able to play with the child and that he could provide a communication tool with the family of the child. Although this project will not go further into this communication tool, this is interesting for the stakeholder since their plans will focus on this aspect.

After discussion with the stakeholder, the concepts showed that there are roughly three types of robots (Figure 44). These robots are placed in a spectrum from abstract and organic, to mechanical and human-like. Together with the client, it was decided to continue the design process with those three robots. This would also allow the later evaluation phase to research the three different designs and the effects of their different shapes on the user.

Figure 44: The three chosen concepts

6.5 From embodiment to behaviour

The selection phase resulted in three different concepts, from modern and simplistic to a human-like robot. These shapes strongly differ from each other and, therefore, allow for different types of behaviour. The shape of each robot can extend or use additional features that will result in form-specific behaviour, that is unique for each of the three concepts (Figure 46-48). This behaviour should facilitate the different tasks that the robot needs to perform as stated in the requirements

<u>The modern robot</u>

- A propellor to fly or move around
- A screen for his face, which can transform into a TV to display information
- A digital mouth, which can also shape letters or other information
- Extendable arms that can perform physical exercises
- Flying by use of a jetpack underneath his belly
- Extendable belly
- A screen on his stomach to show information
- A belly that can open to release objects, such as balloons
- A wheel that extends from his belly that allows him to drive around
- Show confetti or other motivational elements by opening up his belly

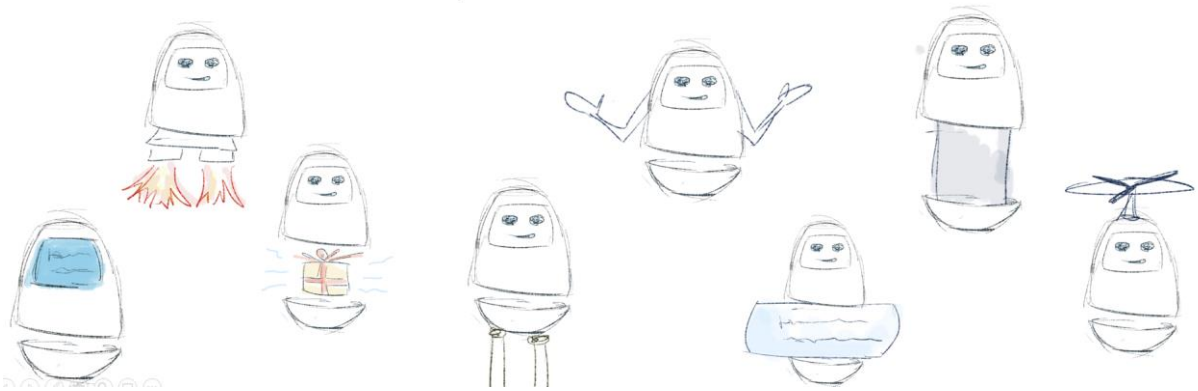


Figure 45: Form-specific behaviour for the Modern Robot

The robot mixture

- Extend the head to an antenna to fly
- Use the antenna as a light that can switch on or off
- Turn on the screen of his face to resemble a tv
- The tv screen can show text, videos or pictures
- Extend the mouth until a large horn that can create objects such as balloons
- Perform human-like activities with the limbs, such as walking or waving
- Show human-like gestures, such as clapping, a high-five or a thumbs up

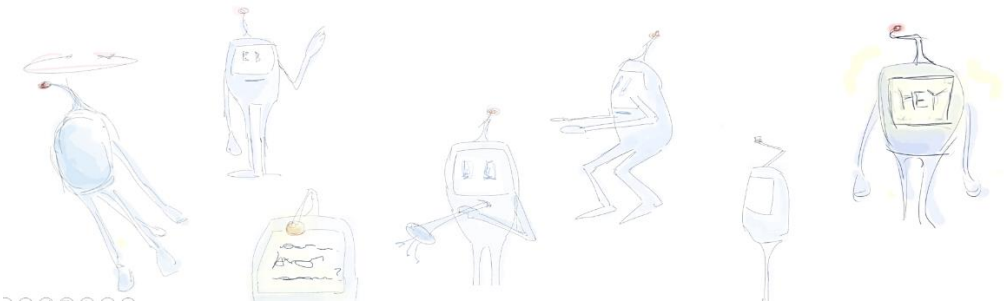


Figure 46: Form-specific behaviour for the Robot Mixture

The mechanical, human-like robot

- Use the limbs to show human-like activities, such sa walking or waving
- Show human-like emotions with the detailed face
- Press the button on his belly to show objects, such as a screen for information or balloons
- Use his antenna to give feedback or emphasise his human-like emotions
- Use the antenna to create objects, such as balloons

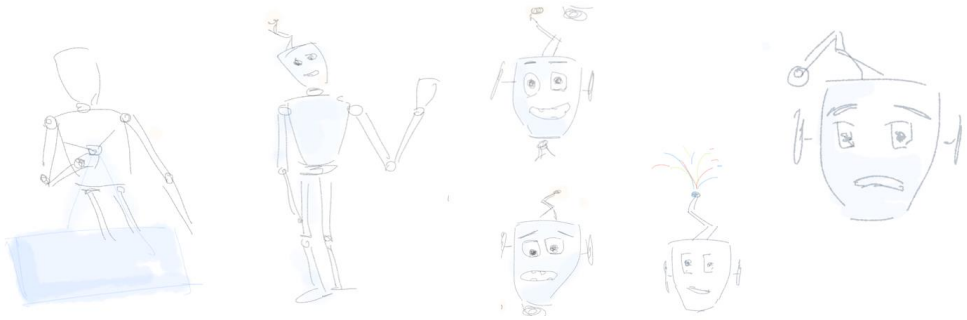


Figure 47: Form-specific behaviour for the mechanical robot

7. Realisation

This section takes the three concepts from the ideation phase and will develop them further so that users can evaluate them later. It will first show the 3D models of the three robot shapes, made with the software Maya. Then, it will show the implemented behaviour which used Maya and Unity for the animations. Last, it will show how the models were implemented into the HoloLens and prepared for the evaluations.

7.1 The models

Figure 48 shows an overview of the three different models. Each of the robots went through some design iterations to optimise the design, which is also visible in Figure 48. The modern robot experimented with the addition of a 'headband' and different eyes and mouths. It was decided to use simplistic eyes, which created the feeling of a screen and matched with his simple appearance. The robot also got a propeller to make him look more interesting and mobile. The mix robot experimented with different eyes and mouths. However, the detailed eyes did not match with his tv-like face. Therefore, the eyes were made more simplistic and pixelated. The first version of the traditional robot had black eyes, which give him a scary feeling. Thus, the eyes changed for more detailed and human-like eyes. This shape of this mouth also changed a bit since this felt a bit unnatural and stiff. Each of the different versions is visible in Figure 48.

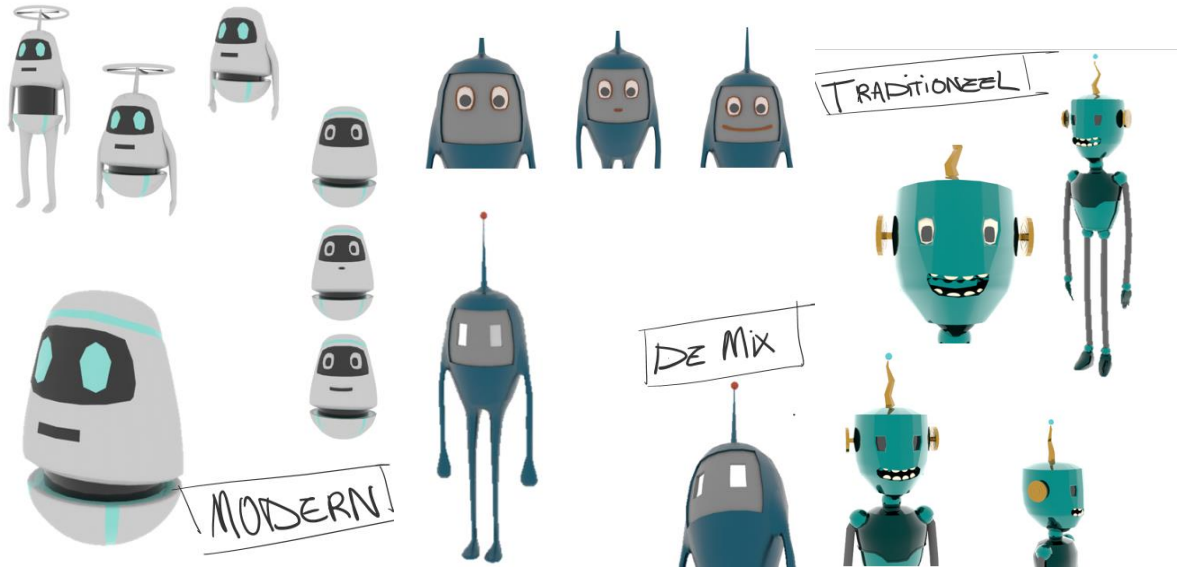


Figure 48: The three robot models

<u>The final designs</u>

The final designs of the robots are visible in Figure 49, where they are placed on a scale from abstract to more human-like.

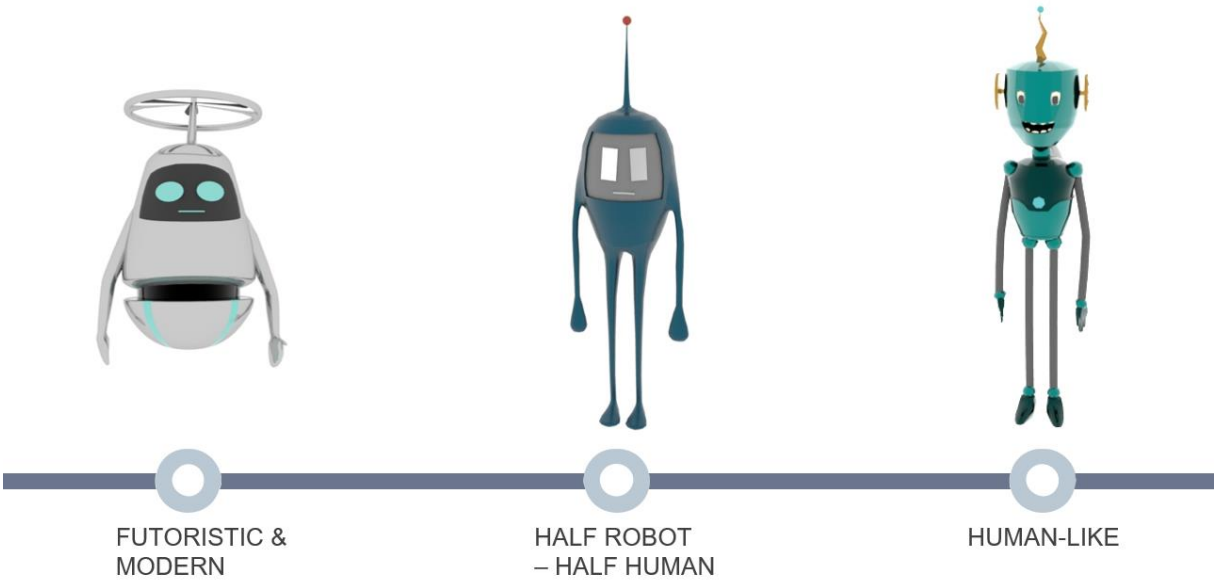


Figure 49: The three robots on a human-robot scale

7.2 The behaviour

After completing the models of the robots, the project continued with implementing their form specific behaviour. The implementation selected a few of the earlier described behaviours since there was not enough time to apply all of the options. The chosen behaviour supported the main tasks of the robot: welcoming the user, providing information and playing with the user. Each of the robots was animated so that they could perform those tasks. However, their behaviour looks different since their shapes are not the same.

The modern robot

The animations of the modern robot made use of Maya (figure 50) and Unity (Figure 51). The different tasks and their accompanying behaviours can be seen in Table 3.

The modern robot	
Task	**Behaviour**
Welcome	Start flying
	Wave
Show information	Display screen
	Generate balloon and show limbs
Start playing	Generate Balloon

Table 3: Tasks and behaviour of the Modern

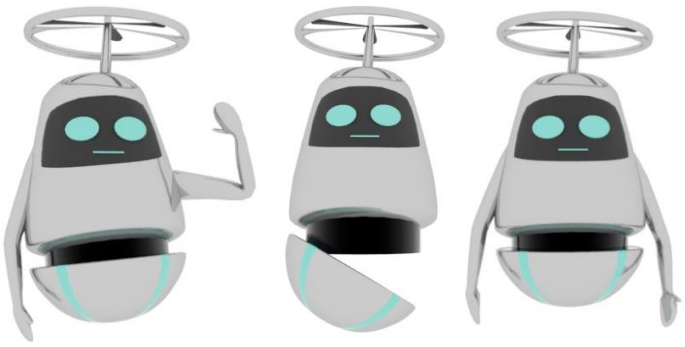


Figure 50: The Maya animations of the Modern Robot

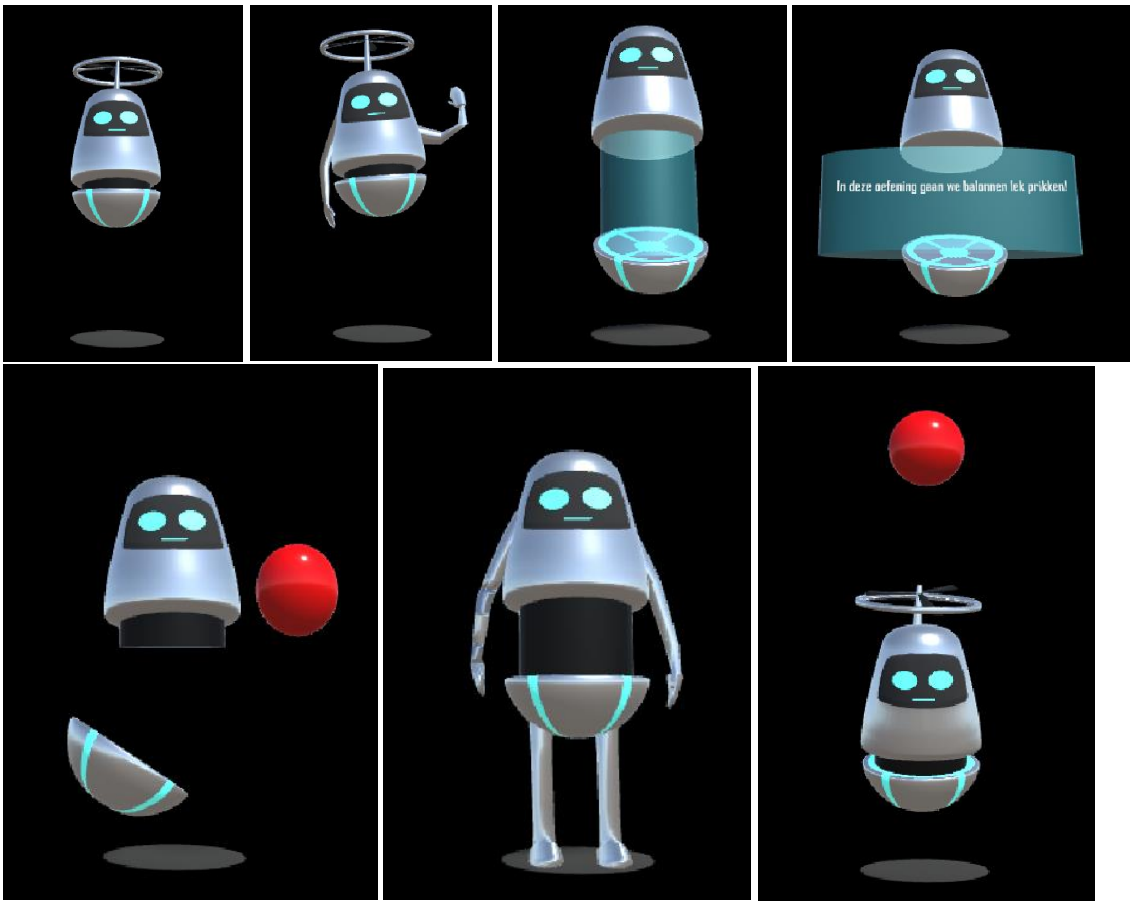


Figure 51: The Unity animations of the Modern Robot

The mix

The different behaviours of the human-robot mixture were made with Maya (Figure 52) and Unity (Figure 53). The different tasks and the accompanying behaviours are shown in table 4.

The Mix	
Task	Action
Welcome	Start flying
	Wave
Show information	Display screen
	Generate balloon and poke
Start playing	Generate Balloon

Table 4: Tasks and behaviour of the Mix Robot

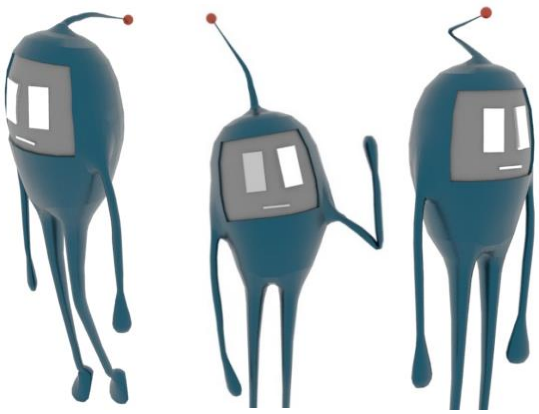


Figure 52: Maya animations of the Mix Robot

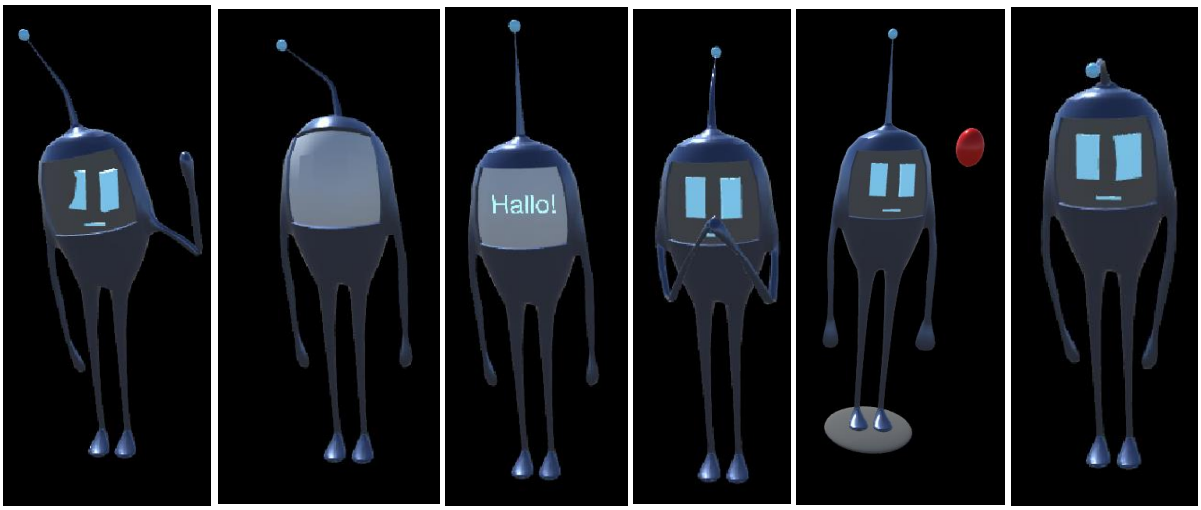


Figure 53: Unity animations of the Mix Robot

The traditional robot

The animations of the traditional robot were made with Maya (figure 54) and Unity (figure 55). Tabel 5 shows the different tasks and the behaviours that presented this.

The traditional robot	
Task	Action
Welcome	Start flying
	Wave
Show information	Display screen
	Generate balloon and poke
Start playing	Generate Balloon

Table 5: Tasks and behaviour of the Traditional Robot

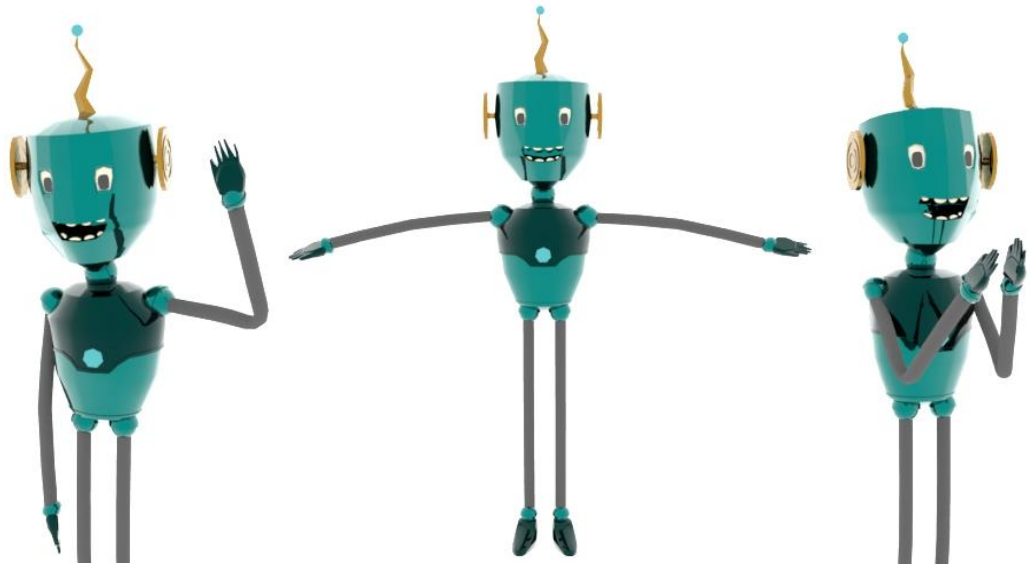


Figure 54: Maya animations of the Traditional Robot

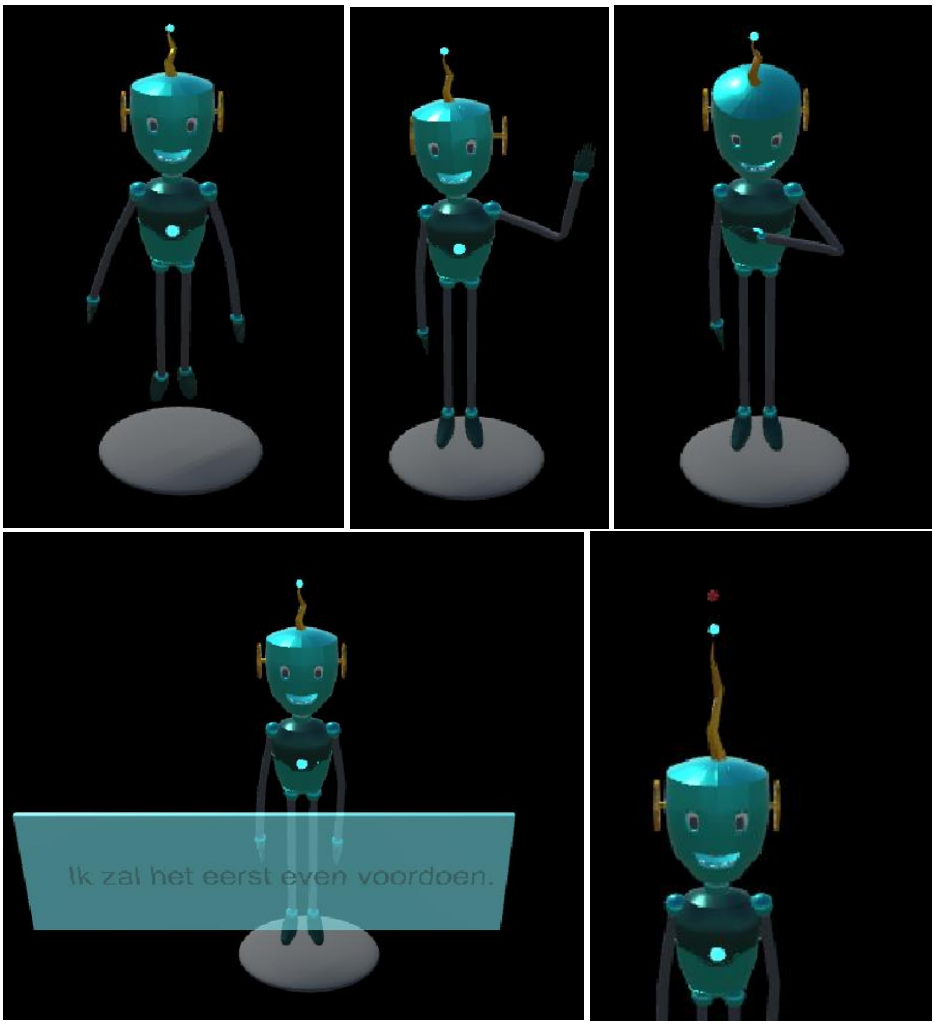


Figure 55: Unity animations of the Traditional Robot

7.3 Preparation for the evaluation

The models and the animations were all implemented into Unity and the HoloLens. This resulted in the scenes, as displayed in Figure 56. Besides that, the three models were used to create Design Cards (Figure 57). The evaluation phase used both the implemented models in the HoloLens and the design cards.

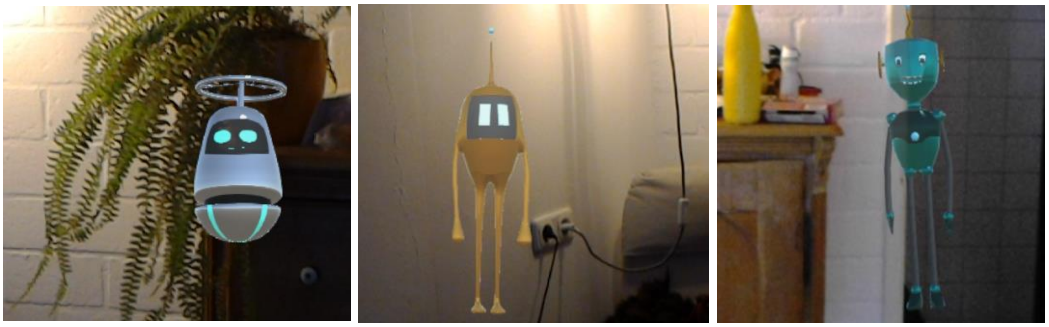


Figure 56: The three models implemented into the HoloLens

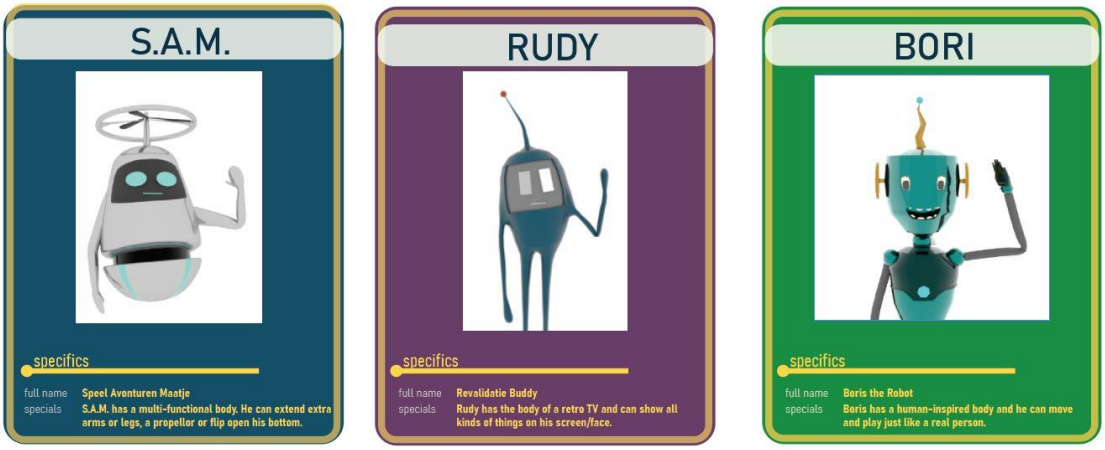


Figure 57: Design Cards of the three models

6. Evaluation

This chapter will evaluate the implemented robots with children during user tests. This section will explain the setup, the goals, the execution and the outcomes of the study. The findings of the evaluation will describe which robot design is best fitting to the target group and will propose potential future improvements.

6.1 Goal

The goal of the evaluation is to answer the sub-questions that follow the main question of this project: "*How to design a digital game guide that can assist children by introducing them to virtual environments, where they implicitly provide information and motivation in a non-therapeutic way in the context of a long hospital stay?*"

The sub-questions of this section aim to evaluate how well the proposed design solutions answer the main research question of this project. They are focussing on the different features of the agent: the visual characteristics and the functional characteristics.

1. *Which of the features of the robots are favoured by the children?*
2. *How effective are the tasks translated into the functional behaviour of the robots?*

6.2 Method

The evaluation exists of two main data collecting parts. First, the participants interact with the three robots and answer a questionnaire for each of them. During this interaction, the robot performs his tasks of welcoming, providing information and motivation, and playing with the user. The second part continues with an interview to further examine the experiences of the participants.

The complete study took place through Skype since physical contact was not possible because of COVID-19. After establishing a video connection with the user, the procedure of the evaluation was explained to the participant. In some cases, the participant received support from an older family member. A later section of this chapter describes the complete protocol of this procedure.

The first part of the evaluation, the interaction with the robots, was done with the HoloLens. The researcher showed the view of the HoloLens with screen share. The participant was asked to 'talk out loud' and perform 'fake' interactions with the agent on his screen. After completing the interactions with each robot, the participant filled in a questionnaire. The questions are based on the Godspeed questionnaire series, and the complete survey is included in Appendix D [21].

After completing the interactions, the user test continued with a semi-structured interview. This interview aimed at gaining an in-depth view on the experience of the user. The questions were about all three agents together and focussed on the embodiment behaviour of the agent.

The following questions were the guideline of the semi-structured interview:

1. Overall, which robot appealed to you the most?
2. Overall, which robot appealed to you the least?
3. Overall, what did you prefer? A robot-like robot or a human-like robot?
4. Which robot did you find most enthusiastic?
5. Which robot did you find most playful?
6. Which robot would you consider to be a buddy?
7. Which robot would be best at giving you feedback?
8. Which robot would be best at giving you information

6.2.1 Setup

The test made use of a video call between the laptops of the researcher and the participant. Both the explanation phase and the interview phase used a video call. The interaction phase used the shared screen function of Skype to show the view of the HoloLens and the evaluation form.

6.2.2 Timeframe

The user tests took place for five days, where the participants could schedule a time that suited them best. Each evaluation session lasted from 30 to 45 minutes.

6.2.3 Participants

A total of 5 children from the target group participated in the evaluation. Some of them already involved in earlier interviews and therefore have some prior knowledge on the project. None of the children had any experience with rehabilitation or extended hospital stays.

6.2.4 Protocol of the procedure

The same user test was conducted for each of the participants. The study consisted of the following steps:

1. Welcome
2. Introduction to the Hololens
3. Interacting with the robot
4. Robot questionnaire
5. Interview
6. Debriefing

Welcome

The introduction started with a technical check to see if the video connection was working

sufficiently. The participants further received a short explanation of the project, the further procedure and their role in the research.

Introduction to the HoloLens
Before starting with the individual robot evaluations, the participants received a short introduction to the HoloLens. This method was inspired by the Evaluations from another Creative Technology student, Amber Eggengoor. The reason for this is that most participants had no experience with the HoloLens or other Augmented Reality glasses. An introducing scene showed them the three robots combined. In this way, the participants could get a feeling of how AR glasses work and already see the three designs. The participant could give instructions to the researcher and directly see how this changed the view.

Interacting with the robot
Before the interaction started, the participants first received an explanation of the different tasks that the robot could perform. These tasks were: welcoming the user, showing information and an exercise, and playing with the user. After the explanation, the robot and its accompanying animations were displayed through the shared view of the Hololens.

Robot questionnaire
The participants filled in the questionnaire directly after seeing the specific robot. The researcher asked the different questions and filled in the answers of the participants into the evaluations document (Appendix E). The participants could make oral remarks and comments during this phase. The process of first showing the robot interaction and then the questionnaire repeated itself for each of the three robots.

Interview
After showing the three different robots, the evaluation continued with an interview. Performing this interview has two reasons. First, it asks the user to compare the three robots with each other, since the earlier evaluation evaluated each robot separately. Secondly, the interview focusses on gathering oral comments and quotes from the participants. This can provide valuable information that became not clear from the evaluations during the first phase of the study.

Debriefing
The session ends by thanking the participants for their contribution and a short explanation of the continuation of the project.

6.3 Results
This section discusses the results of the user evaluation. First, it presents the interview results of each different robot, followed by a combined view (Appendix E). After that, it discusses the results of the Godspeed questionnaire.

6.3.1 Results from the interviews

This section combines the results from the interviews and the oral comments made during the questionnaire. It provides a textual evaluation of the three robots and will finish with comparing them to each other.

S.A.M.

Some participants described Sam as sweet, cosy, welcoming, friendly and funny, and they stated that they enjoyed his appearance. For those participants, he also scored high on enthusiasm and playfulness. One of the participants said: "He is just small and compact, which makes him able to drag you everywhere in his enthusiasm." They also preferred his way of displaying information by opening up his body and creating a screen. Although the modern robot seemed less human, he was considered active and funny because of his ability to fly and move around, which also increased his playfulness and ability to play games with the user.

According to the participant, Sam's shape looked natural and organic because of the simple form and a small number of details. His soft and rounded shape also added to a feeling of sympathy from the user. The bright and shiny colours increased the liveliness of Sam. The unique features of this robot also gave him something interesting, like his propeller, his ability to float or open up his belly. According to the participants, they felt all naturally and nicely fitting together.

However, his movements and facial expressions seemed unreal and stiff. His simplistic eyes and mouth were the main reasons for his lack of emotion and facial expressions. One of the participants stated: "I wouldn't describe him as kind, but also not as *not* kind. He just lacks emotions." This was the same for his ability to motivate and give feedback. The robot further didn't look like he had consciousness or that he could think or make his own decisions. Instead, he just poked his finger to the ballon while staring straight ahead. "He didn't look like he thought about it and actually wanted to poke the ballon" according to one of the participants. He didn't give feedback or reaction from things that happened in his surroundings, from either himself or the user. This made the participant feel like his movements were very fixed and movie-like. His lack of simultaneous actions also negatively impacted his appearance.

Sam's awareness and believability could increase with the addition of small extra movements, such as a head nod or body rotation. The addition of emotion and facial changes could also increase the feeling of consciousness and excitement. An example from the movie StarWars was named, where the robot could rotate and move his face to look more lively. This could be a valuable addition for Sam.

Overall, the robot-feeling and the simplicity of Sam's appearance were preferred over a human-looking robot by two participants. They felt that such a robot could do anything or extend to different shapes without creating an unreal feeling. One of the participants stated: "Robots can do anything. Just open a little hatch and extend a third arm and everyone will believe it." This gives the design a lot of freedom to implement different functions, such as flying, rolling or walking, while still maintaining a simple shape. However, almost all participants found his face too simplistic. The round eyes and the thin line of his mouth were too abstract and didn't felt personal. Especially in a rehabilitation process, it is important to have a connection with your buddy and form a bond. For this, the robot should be able to show emotion and facial expressions. Therefore, Sam's appearance should be made more human and detailed. Besides that, adding small movements that connect the whole body can increase the liveliness of the robot.

Rudy

The robot appealed the least to the participants, and they described him as not so friendly or happy, and a little bit dull. He didn't have eye-catching or 'cool' elements. One of the participants said: "The main character from a game or movie always has something exciting or a cool gadget. Rudy just doesn't have such a thing." However, the robot increased the feelings of seriousness and believability when explaining information or feedback. But at the same time, it was stated that all robots would be believable when there is a personal bond between the user and the robot.

According to one of the participants, Rudy has some small movements that work together, like his body rotating when he waves. This made the action a bit more nuanced and more energetic. But one of the participants stated that he looks aimless from his eyes, and nothing happens on his face. Especially during movements, he keeps staring just straight ahead. Therefore, it made a few participants feel like the robot is unaware of his surroundings and has no consciousness. It also made him look like he couldn't show emotion, and he can only do a pre-programmed movement. One of the participants noted: "It looks like he is in sleeping mode and not able to show any emotion or connection." Furthermore, one participant stated that his movements were looking stiff or slow, and mostly happened one after each other. However, his whole body was more organic and fluently shaped, which compensated the somewhat stiff movements.

The moment where the robot opens up his screen to show information was evaluated both positive and negative. On the one hand, participants thought it was a nice and creative way which fitted with the shape of the robot. But at the same time, it forms a boundary when the face is nog longer used to communicate facial expressions.

Furthermore, the participants noted that the robot doesn't radiate energy or positive feelings. One of the participants noted: "It seemed like the robot is not really trying his best to be enthusiastic or positive."

Overall, both the shape and the actions of the robot did not provoke any funny or sweet feelings. One participant pointed out that this is mainly because of his lack of showing emotions through his face. Rudy could improve by the addition of more human-like features in his face so that he can easier show emotion and character. This would also make it easier to bond with the robot.

Bori

The mechanical robot was liked the most for some participants, because of his more traditional robotic feeling. They considered him as welcoming, friendly and funny. He further provoked a lot of empathy because of his human-like aspects. Especially the eyes and mouth or the limbs increased this human aspect. "It gives him more consciousness, and it feels like he really goes for it", according to one of the users. For one participant, this human-likeness and the fact that the robot is firmly standing on the ground made him feel like a better buddy than the others.

One participant noted that Bori looked a lot like a robot on the outer side, but he appeared to be more human through his actions. One of the participants indicated that despite his mechanical looks, his movements were organic and smooth. For example, he first looks down to his belly to check where to press it. These small movements make him look like he thought about it before executing the actions. This also increased the feeling of consciousness and awareness. One of the participants stated: "It made him look like he is thinking about what he should do and that he is aware of his surroundings and his impact on this." He continued with the example of the robot launching a ball and then catching this with his both hands. The robot also moved multiple

different parts of his body at the same time, which made him more lifelike. However, his movements were still a bit stiff, and there were little simultaneous movements.

A few participants were not fond of the Bori, and they described him as old-fashioned and with too many details. They preferred a more simple and less complicated shape. These participants also felt like this robot provoked a more elderly and wise feeling, and that he would be better at explaining an exercise or providing information than the other two robots. Furthermore, one of the participants noted that Bori looked a bit dark at first and that he was not sure if the robot was evil. He pointed out that this could be because of his darker colours. However, his face looked so happy and radiant that this feeling faded quickly again. Furthermore, the robot was not described as very pretty, but all the elements fit together into a whole.

Altogether, participants noted that Bori radiated energy and a feeling of 'I want to do this!'. Especially his facial expressions, with his eyes and mouth, made him look happy and alive. It increased the perceived enthusiasm, friendliness and cheerfulness, and it gave him more character and personality. Also, his little extra movements added to this feeling. And the colours and detailed design of the robot made him look more energetic and stand out from the other two robots.

Comparing the interview results

Overall, it differed quite a lot in which robot could be the best 'buddy' to each participant. Most participants that liked one robot most, also thought that robot would be the best buddy for them. However, they often believed that all robots could feel like a buddy to them. Sam looked more like an energetic little ball that could fly after you and try to catch you. He would be good at helping you and be serious about his task. Bori and Rudy were seen more as playing buddies, because of their limbs and ability to do things with it.

Bori and Sam could give the best feedback and information, according to the participant. Rudy was less popular because his face is the tool for providing the information. One of the participants was a bit terrified by this transformation of a face to a screen and described it as "tearing open his face". But his wobbly antenna and bright screen were evaluated positively. Sam was more serious to the participants, and would, therefore, value his input more. His face was visible during the communication, which allowed for facial expressions, but his body was a little stiff. His way of showing information gave the robot something extra. Bori was evaluated the best for showing emotions through his face because he has more details and human-likeness. He also had more body flexion. Both these aspects increased his ability to give nuanced feedback and information. However, his way of showing the news, through a text sign, was considered as neutral and not unique.

Participants that liked Sam thought that his appearance could improve when the facial features of Bori would combine with the face of Sam. At the moment, Sam was once described as "an empty shell without emotion" where Bori seemed to have his own will. Two other participants doubted between Sam or Bori. They liked the two very different shapes of them both. Therefore, they couldn't decide on whether they preferred a robot-robot or a human-robot. However, Bori had a stronger drive, and he radiated more energy. Bori also seemed like he performs actions by himself, where the others look like they are programmed to do so.

6.3.2 Results from the Godspeed questionnaire

S.A.M. the modern robot

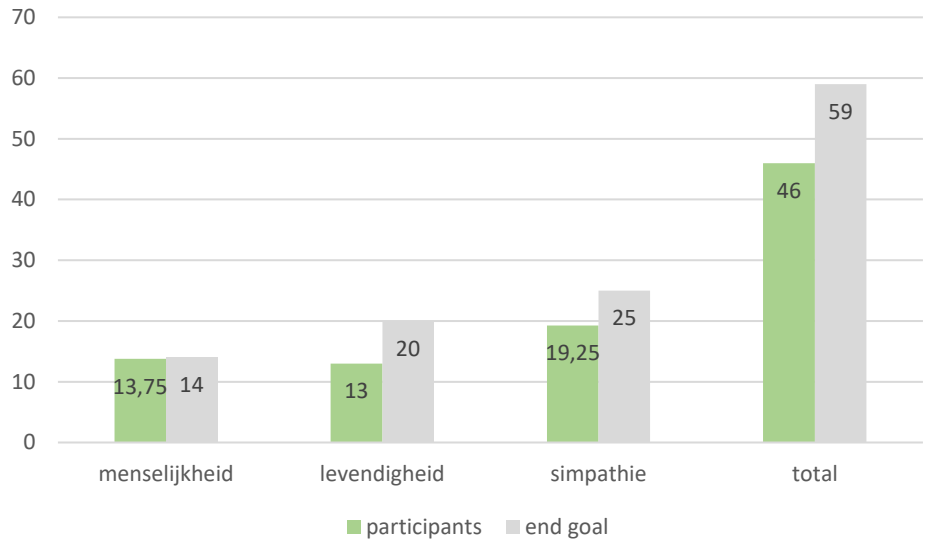


Figure 58: The evaluation results of the Modern Robot - SAM

The graph in Figure 58. shows the results of the Godspeed questions about the modern robot with the desired scores of the stakeholder. This stakeholder view is the desired outcome of what the robot should achieve in the end. The Figure shows that the robot approximately meets the desired human-likeness. During the interviews, participants often described the robot as a robot-robot, instead of a human-like robot. Despite his robotic appearance, the robot has features, like his arms or legs, that gave him a more humanlike feeling. The results from the graph show that this amount of human likeliness is enough to reach the desired score of the stakeholder.

The graph further shows that the liveliness of the robot is below the desired score. During the interviews, participants often stated that the robot was not able to show emotions or expressions with his eyes and mouth. Besides that, his movements were stiff and not effecting his complete body, but only a small part of it. These aspects made the participants feel like the robot had no awareness of himself and his surroundings, and as if he was preprogrammed to do specific tasks without deciding so himself. These interview outcomes match with the low liveliness score from the graph.

The third category from the graph shows that the amount of sympathy is again lower than the desired score. The lack of showing emotion and consciousness can explain this low value. Some participants also noted that this made it harder to form a personal bond with the robot. However, as shown in the interview results, some participants found his round and organic shape to be friendly and soft, which could increase their sympathy again.

Overall, two of the three categories were strongly below the desired score and therefore, fail to meet the vision of the stakeholder. Results from the interviews showed that the shape and appearance of the robot appeal to the user. However, the robot did not show enough emotion or character through his facial expressions, and his movements were too stiff and lifeless.

Rudy

Figure 59: The evaluation results of the Robot Mix - Rudy

The graph from Figure 59 shows the evaluation results of the Robot Mix, Rudy. The human likeness of the robot reaches the desired value of 14. Results from the interview stated that the robot was not describe3d as either human or machine. However, his arms and legs made participants feel like he had human-like aspects. This can explain the value from the graph, and therefore, the robot is considered as human enough.

The liveliness of the robot is below the desired score of 20. Interview results showed that the robot often lacked emotions or focus on the user and that his movements where stiff. Some of the participants noted that the robot seemed to be in sleeping mode and not aware of his surroundings. They further noted that his organic shape made him look more fluent, which compensated a bit for his stiffer movements. These aspects could explain why the value of the liveliness is lower than the desired value.

The sympathy of the user towards the robot, scores below the desired value of 25. Main points from the interview pointed out that the robot couldn't show emotion or a connection through his facial expressions. This was especially the case when his face transformed from face to screen. Furthermore, the robot was described to have no real catchy or exciting element that makes the user interested or engaged in the robot.

Altogether, the robot scores low on the categories liveliness and sympathy and is not able to meet the total desired score of the stakeholder.

Bori

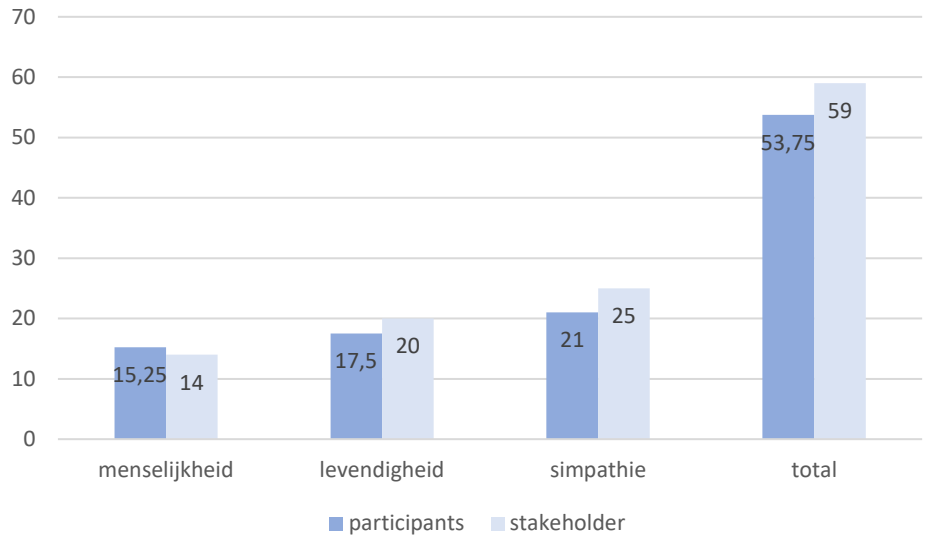


Figure 60: The evaluation results of the Traditional Robot - Bori

The graph from Figure 60 shows that the robot scores higher than the desired human likeliness value of 14. This matches with the interview results. Participants stated that the appearance of the robot was very robot-like, but his actions were humanlike. They further said that he had a lot of humanlike characteristics, such as eyes, a mouth, arms and hands. However, his score was higher than desired, and the question arises whether the robot looks too much like a human. When looking back at the interview results, the participants often stated that the mechanical robot had human-like characteristics, such as his eyes or mouth. They further said that this increased his ability to show emotion and connect with the user. There were no remarks about the robot being too much human-like. Therefore, it can be said that the mechanical robot doesn't look like a human too much.

The liveliness of the robot is below the desired value of 20. The interview results can partly explain this since they noted that the robot had stiff and nonsimultaneous movements. However, participant also noted that the robot radiated energy and enthusiasm and that it looked like he had an awareness. This was mostly because of his facial expression and the little movements that he made. Since the value is still lower than the desired value, it shows that these aspects should develop further to increase his liveliness.

The robot scored below the desired value on sympathy. The interview results again showed that they could bond with the robot because of the facial expressions and happy energy. However, the value is not yet meeting the desired height, and therefore, these aspects should be increased and developed further.

Comparing the questionnaire results

To compare the results to each other, they are put together in one graph along with the stakeholder's view in Figure 61. This stakeholder view is the desired outcome of what the robot should achieve in the end. The figure shows that the mechanical robot scores best from the three robots in all categories. It further indicates that the modern robot scores least in most categories. It also says that all robots lack some points in the category liveliness and sympathy.

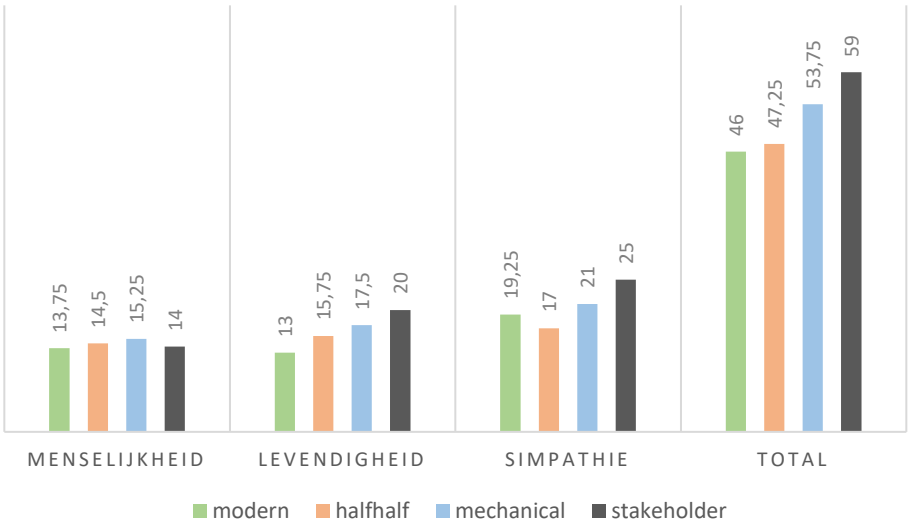


Figure 61: The combined graph of the evaluation results

When looking at the first category, the figure shows that the desired value of humanity is a score of 14. All robots approximately reached this score and are therefore considered to be human-like enough. However, especially the mechanical robot scored a bit above this rate. When comparing the interview results with this graph, it shows that the other two robots lacked specific facial elements, such as eyes with pupils or a mouth. Furthermore, the participants stated that both the modern and the 'half-half' robot seemed to be stiffer and less aware of themselves and their surroundings, compared to the mechanical robot. These interview outcomes match with the results from Figure 61. since they both score lower than the mechanical robot.

The second category of the graph shows that the desired score of liveliness is 20, but that none of the robots reached this value. When looking at the differences between the three robots, it shows that the modern robot has the least liveliness and the mechanical robot the most. The interview results confirm this outcome. Participants stated that the modern robot did not react to its environment or the participants. His movements did not affect his complete body, but only the separate limbs. Some participants found that the robot did not have a soul or an awareness. The second robot, the HalfHalf, was rated more organic and livelily by the participants. The main reason for this was that the robot incorporated his whole body during movements. However, this robot also lacked emotion and a lively appearance, according to the interview results. The third robot, the mechanical robot, was evaluated best during the interviews. His facial elements, such as eyes and mouth, resulted in a better ability to show emotion and energy. The interview results correspond with the data from the graph. Which also indicates that the modern robot is evaluated worst and the mechanical robot best.

The third category of the graph describes the likeability and shows the desired value of 25. This is the maximum scores and shows that the stakeholder values this aspect the most. The figure shows that this time, the modern robot scores higher than the 'half-half' robot and that the mechanical robot still scores the best. These results correspond with the interview results. Throughout the interviews, the 'Half-half' robot appealed the least to all participants. A participant stated that he looked less energetic and vibrant. The interview results show that the modern robot appealed to the participants more often, and they saw him as friendly and enthusiastic. The interview results further show that the mechanical robot scored best and participants stated that it was easier to form a connection with him. These interview outcomes

resemble with the findings shown in the graph. However, the figure shows that all robots score beneath the desired value of the stakeholder. They are therefore not considered as likeable enough.

6.5 Conclusion evaluation

The comparisons of both the interviews and the questionnaire show that the participants preferred the mechanical robot over the other two designs. The interview results show positive results about his appearance and his movements. Participants thought his facial expressions could convey emotion and energy the best, and that he appeared to have a conscious and an awareness of his surroundings. Furthermore, the results of the questionnaire show that this robot has the least differences with the desired outcome from the stakeholder, compared to the other two robots. Therefore, the mechanical robot appears to be the preferred design by the participants. This outcome of the user tests leads to the decision to focus further research on the mechanical robot. However, this robot didn't meet all the desired values of the stakeholder and still has room for improvements. The next section will propose points of attention to improve the design and get him closer to the desired view of the stakeholder.

6.6 Points of improvement

The results of the user study showed that the mechanical robot did not meet all the desired aspects of the stakeholder yet (Figure 62). Participants evaluated the robot less than desired in the categories of likeability and animacy. Especially the likeability was seen as important by the stakeholder. This raises the question about how the robot can be improved to reach the desired values. Therefore, the two categories are further analysed. The category of anthropomorphism will be left out of the analysation since the robot scored high enough here.

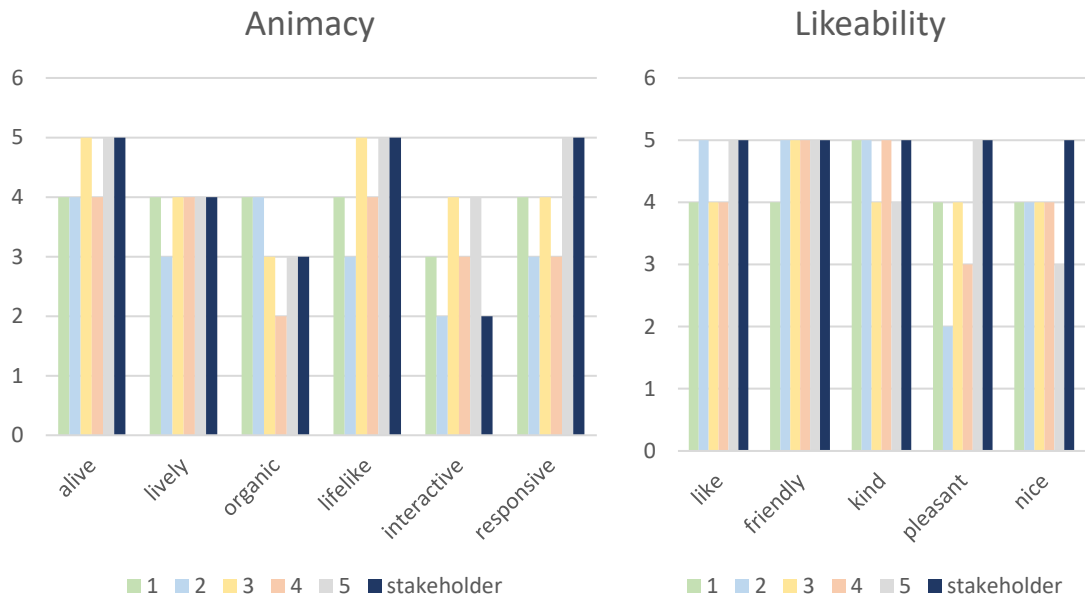


Figure 62: The graphs of the questionnaire results of Animacy (left) and Likeability (right)

The graph of Animacy in Figure 62 shows that most of the aspects could be improved. The participants only evaluate the robot as approximately desired on the aspects 'organic' and 'interactive'. Therefore, the robot should increase in the categories: alive, lively, lifelike and responsive. Focus points are then to make the robot look more like a living creature, more energetic and more responsive.

The graph of likeability in Figure 62 shows that the robot should improve on all the individual aspects. However, only one participant thought that the robot was not friendly enough where the others valued this as enough. Therefore, this category will not be the focus point of the improvements. The other aspects were all evaluated less by at least two or more participants, and are therefore seen as points to improve. These points are about whether the participants say the like the robot, and if they think he is nice, pleasant and friendly.

The interview results can offer some points of improvement that were noted by the participants (Figure 63f). These negative points might be the cause of why the robot doesn't reach the desired scores and can offer a guiding line to improve the mechanical robot. The following points of improvement were taken from the interview results:

- The number of small movements. For example, looking down at the belly before touching it, or shifting the feet after a certain amount of time.
- The smoothness of the movements.
- The number of simultaneous movements. For example, shuffle the feet while the right hand is waving.
- The number of energetic animations. For example, enthusiastic clapping of the hands or waving with a lot of energy.
- Movement of the face, so that more facial expressions are possible and the robot looks alive more. Such as a moving mouth or different emotions by changing the shape of the face.
- The responsiveness of the robot so that he is better able to react to the user with different types of reactions.
- The perceived prettiness of the appearance, so that it better fits with the beauty preferences of the target group. This is about the shape, the number of details, and the colour schema. Some participants liked the number of details and the colours, where others preferred a more simple form and thought the colours were too dark. This shows that the preferences among the children are spread, and some more user input is needed to find out what the most common or overlapping choices are.

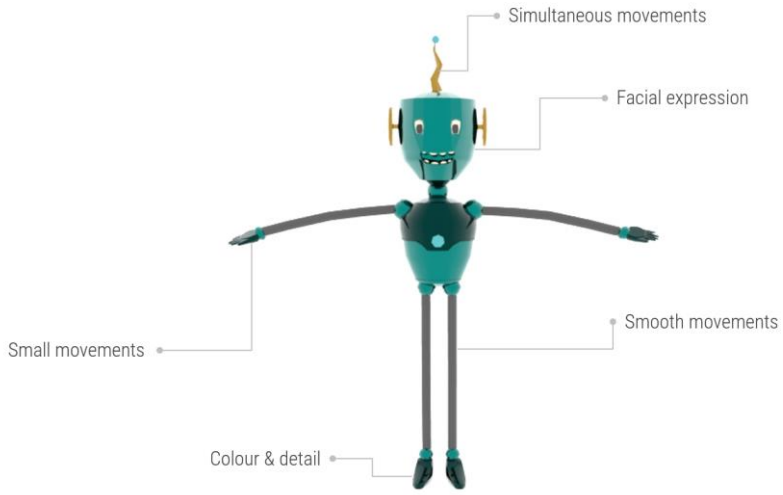


Figure 63: The proposed design improvements

7. Conclusion

This project explored the aspects of a digital agent, used for Physical Therapy with the HoloLens. The Design Process of this project focusses on designing this digital agent. Research was first done to provide this design process with the necessary information about aspects of a digital agent and physical therapy with children. The findings from the user tests and the earlier research from literature, related work, lo-fi evaluations, the ideation, the realisation and the evaluations can lead to an answer to the research question of this report.

"How to design a digital game guide that can assist children by introducing them to virtual environments, where they implicitly provide information and motivation in a non-therapeutic way in the context of a long hospital stay?"

The Design Process started by defining the main tasks of the agent, which are welcoming the user, giving information and feedback, and activating and motivating to stimulate moving. The Design Process continued by developing the embodiment of the agent, which resulted in three designs of robot agents. Last, the process researched form-specific behaviour for each of the shapes. The thesis concluded with an evaluated design solution, implemented into the HoloLens.

The user study with children resulted in a couple of findings. First, the Mechanical robot 'Bori' is the preferred design, according to children from the target age. The robot was evaluated in three aspects: anthropomorphism, liveliness, and animacy. These aspects showed to be relevant during earlier research. The evaluation results showed that the design of the robot has a sufficient amount of human likeness, due to his human-like aspects such as the mouth, eyes and limbs. These aspects also allow the robot to perform physical exercises, as was earlier stated as necessary by therapists. His human-likeness also allowed the participants to form a relationship with the robot. The liveliness and the animacy of the robot were evaluated as not enough yet since the robot looked a bit stiff, had not enough simultaneous movements, and his face did not allow for facial expressions. The future addition of facial expressions could be a useful tool to provide feedback, according to the context analysis. Next, the design was not evaluated as entirely nice, pleasant, and friendly by the participants, while the stakeholder found this to be important.

8. Discussion

The following section will critically look at the performed Design Process from this research, the prototype and the evaluation. It will conclude with recommendations for future work.

The research

This thesis aimed to research the aspects of a digital agent and physical therapy for children. Based on this research, the thesis continued to design an agent by following a three-step method where tasks are followed by embodiment, followed by behaviour. However, this is not a linear process, but it can circulate from behaviour back to tasks, to see if the developed behaviour support the tasks. This circular process can repeat itself during multiple iterations, and in this way, the development of an agent can improve. This process could be optimised by implemented various rounds of user involvement after each completed step, which also resembles with the Creative Technology Design process. In this project, users were only involved after the task-research and the embodiment and behaviour research combined. Although the card evaluations evaluated different embodiments with the users, the designs of this project were not assessed here. In future work, extra user involvement could be valuable between the proposed embodiment and the implementation of the concepts.

The stakeholder, experts and children were involved in the process multiple times, and the process took their input into account. The project conducted the stakeholder every one or two weeks. Next, one of the therapists was already involved with HoloMoves. This could have resulted in a coloured opinion on the topic and the preferences of the therapist. This was only the case for one of the three therapists, but this could have an impact on the results because of the small sample size. Next, the project gathered feedback from children. However, no children from the target group of rehabilitation were involved in the process. The viewpoints of the children used in this project can differ from the opinions of patients. Besides that, this project only conducted two sets of interviews with a total of six different children. So most children participated in the research twice, which did not give a broad view of the preferences and opinions of the target group. The project planned to perform research on multiple schools, but this was not possible due to the COVID-19 situation.

Prototype

Multiple potential useful aspects were found during the research and can be found in the Design Guidelines in the requirements chapter of this thesis. However, the chosen design did not implement them all due to the available time of this project, but future research can consider them. The first aspect is the addition of audio, such as sound effects, a voice of the agent or music. Sounds can also assist the explanation of exercises or other information. A second aspect is the additional ways of providing feedback, such as facial expressions, gaze, mouth, and gestures with the hands and arms. Next, the social relationship with the agent could improve over time to simulate a human-to-human connection. Next, the agent could make use of random animations to increase the liveliness. Next, the current prototype does not allow for communication between the user and the agent, but multiple-choice options or buttons could provide an efficient communication tool. Besides that, the prototype could implement choices and decisions for the child to make.

The user study used a prototype with a fixed set of tasks and functions, and the Wizard of Oz took care of the interaction with the robot. However, this did not allow the child to interact with

the robot fully and naturally. Therefore, there was no spontaneous interaction between the child and the robot, which could have affected the evaluation.

Besides that, this project did not thoroughly research the content of the robot. The tasks of the robot are precise, the project did not implemented medical information or data on physical rehabilitation.

Evaluations

The evaluations conducted a small sample size of five participants, which is a low amount to draw conclusions on. Besides that, some children stated that they found it hard to answer the questions or give a score, which can also result in less trustable results. Besides that, the participants were mainly boys, although no big difference have been noticed during the interviews, this could potentially influenced the evaluation outcomes. For future research, the study could use a larger sample size with both girls and boys. Furthermore, all of the participants in the user study had no experience with rehabilitation. Their views can differ from the actual needs of a patient, the full contribution of the agent, and the health effects in rehabilitation regarding isolation and loneliness. Therefore, the results can also be different than for children from rehabilitation centres. The evaluations are also not completed with therapists due to the available time of this project.

During evaluations with the client, they claimed that they liked the 'Half-half' robot or 'Rudy' the best, although the participants of the user study preferred the mechanical robot. However, this project mostly based its outcome on the results of the user study. The sub-optimal chose may be made by valuing the outcome of the user study above the stakeholder view. The stakeholder has a long-term vision in his mind and will also look at the opportunities and technical options of the design. The evaluations with the children did not consider this expert view. Therefore, it is the question whether the mechanical robot 'Bori' is also the optimal design for the company HoloMoves.

Besides that, the setup of the evaluation and the usage of the HoloLens was not optimal. Due to the COVID-19 situation, the participants were not able to fully experience the possibilities of the HoloLens since they couldn't use it. This could affect their evaluation of the robots. Besides that, there were some technical difficulties and hiccups with the connection through Skype, which made the evaluations less smooth during certain moments.

Future recommendations

The robot design could already improve according to the aspects noted by the participants of the user study. Participants stated that the robot could improve the number of small movements, the smoothness of his movements, the number of simultaneous movements, the number of energetic animations, the movement of the face, and the responsiveness of the robot.

Besides that, future research can further examine the preferred embodiment and behaviour of children. This could be done with more design iterations in combination with co-design sessions with the children. The Design Card system could also assist the co-design sessions and provide quick iterations with the children. These cards could display different robotic aspects or elements so that children can combine and design their optimal robot.

Furthermore, the design can develop further by making it more interactive and responsive. This could be done by implementing a voice and providing personalised feedback and text to the

user. Besides that, it could implement more animations that respond to the user. Besides that, user-specific elements can be taken into account to personalise the agent and fit to more types of users with different preferences and disabilities. Next, the element of choice and personalisation can also allow the user to personalise and adapt the agent, which could increase the bond between them.

Future developments can also focus on implementing the space of the room. The design process of this project mainly focused on developing the agent itself, but future research could also focus on different ways to use the physical space around the agent. In this way, the possibilities of the HoloLens can be used optimally.

References

[1] T. Bickmore, "Relational agents for chronic disease self management," *Health Informatics: A Patient-Centered Approach to Diabetes,* pp. 181-204, 2010.

[2] S. Khan, A. Camacho, and D. Novick, "Recipe Hunt: Engaging with Cultural Food Knowledge using Multiple Embodied Conversational Agents," in *International Conference on Intelligent Virtual Agents*, 2017: Springer, pp. 209-212.

[3] I. Poggi, C. Pelachaud, F. de Rosis, V. Carofiglio, and B. De Carolis, "Greta. a believable embodied conversational agent," in *Multimodal intelligent information presentation*: Springer, 2005, pp. 3-25.

[4] T. W. Bickmore, L. M. P. Vardoulakis, and D. Schulman, "Tinker: a relational agent museum guide," *Autonomous agents and multi-agent systems,* vol. 27, no. 2, pp. 254-276, 2013.

[5] S. Bernardini, K. Porayska-Pomsta, and T. J. Smith, "ECHOES: An intelligent serious game for fostering social communication in children with autism," *Information Sciences,* vol. 264, pp. 41-60, 2014.

[6] A. Mader and W. Eggink, "A design process for creative technology," in *DS 78: Proceedings of the 16th International conference on Engineering and Product Design Education (E&PDE14), Design Education and Human Technology Relations, University of Twente, The Netherlands, 04-05.09. 2014*, 2014.

[7] K. K. Bowden, T. Nilsson, C. P. Spencer, K. Cengiz, A. Ghitulescu, and J. B. van Waterschoot, "I Probe, Therefore I Am: Designing a Virtual Journalist with Human Emotions," *arXiv preprint arXiv:1705.06694,* 2017.

[8] M. Valstar *et al.*, "Ask Alice: an artificial retrieval of information agent," in *Proceedings of the 18th ACM International Conference on Multimodal Interaction*, 2016, pp. 419-420.

[9] P. Wilkinson, "A brief history of serious games," in *Entertainment computing and serious games*: Springer, 2016, pp. 17-41.

[10] P. A. Rego, P. M. Moreira, and L. P. Reis, "Architecture for serious games in health rehabilitation," in *New Perspectives in Information Systems and Technologies, Volume 2*: Springer, 2014, pp. 307-317.

[11] L. L. Kramer, S. Ter Stal, B. C. Mulder, E. de Vet, and L. van Velsen, "Developing Embodied Conversational Agents for Coaching People in a Healthy Lifestyle: Scoping Review," *Journal of Medical Internet Research,* vol. 22, no. 2, p. e14058, 2020.

[12] T. S. Behrend and L. F. Thompson, "Using animated agents in learner-controlled training: The effects of design control," *International Journal of training and Development,* vol. 16, no. 4, pp. 263-283, 2012.

[13] H. C. van Vugt, E. A. Konijn, J. F. Hoorn, I. Keur, and A. Eliéns, "Realism is not all! User engagement with task-related interface characters," *Interacting with Computers,* vol. 19, no. 2, pp. 267-280, 2007.

[14] J. Xiao, J. Stasko, and R. Catrambone, "Embodied conversational agents as a UI paradigm: A framework for evaluation," *Embodied conversational agents-let's specify and evaluate them,* 2002.

[15] N. L. Schroeder, O. O. Adesope, and R. B. Gilbert, "How effective are pedagogical agents for learning? A meta-analytic review," *Journal of Educational Computing Research,* vol. 49, no. 1, pp. 1-39, 2013.

[16] H. C. Van Vugt, J. F. Hoorn, and E. A. Konijn, "Adapting empathic agents to user experiences," in *AAMAS'04 Workshop on Empathic Agents. New York*, 2004.

[17] S. Kopp, J. Allwood, K. Grammer, E. Ahlsen, and T. Stocksmeier, "Modeling embodied feedback with virtual humans," in *Modeling communication with robots and virtual humans*: Springer, 2008, pp. 18-37.

[18] A. Camacho, A. Rayon, I. Gris, and D. Novick, "An Exploratory Analysis of ECA Characteristics," in *International Conference on Intelligent Virtual Agents*, 2014: Springer, pp. 95-98.
[19] R. Klaassen, P. Di Bitonto, G. J. van der Burg, K. Bul, and P. Kato, "PERGAMON: A serious gaming and digital coaching platform supporting patients and healthcare professionals," in *International Conference on Enterprise Information Systems/International Conference on Project Management/International Conference on Health and Social Care Information Systems and Technologies, CENTERIS/ProjMAN/HCist. Porto, Portugal: SciKA*, 2016.
[20] T. Beinema *et al.*, "Council of coaches a novel holistic behavior change coaching approach," 2018.
[21] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *International journal of social robotics,* vol. 1, no. 1, pp. 71-81, 2009.

Appendix

A. Table of ECA features

agent	goal	targetgroup	dimensions	shape	movemen	gestures	body	screen	style
Pergamom	coach	children	3D	animal	motion	arms	full body	partly	cartoon, animated
Laura	adviser	adults	2D	woman	no motion	hands, arms	upper body	full screen	cartoon
Eliza			3D	woman	motion	no	upper body	full screen	animated
Recipe hunter	coach	adults, children, gamers	3D	woman	motion	hands, arms, body	full body	partly	animated
Arial	coach, buddy	gamers	2D	boy	no motion	hands, arms	upper body	partly	cartoon
Evi	adviser	adults	2D	woman	motion	hands, arms, body	full body	partly	animated
Clippy	coach	adults, children	3D	object	motion	no	full body	partly	cartoon, animated
Hop	coach, buddy	gamers, children	3D	boy	motion	arms, hands	full body	partly	cartoon, animated
Greta	adviser	adults	3D	woman	motion	arms, hands	full body	full screen	animated
Anna	adviser	adults	2D	woman	no motion	no	upper body	partly	cartoon
Tinker	adviser	adults, children	2D	robot	motion	arms	full body	full screen	cartoon, animated
Alice Wonderland	adviser		3D	girl	motion	arms, hands	full body	full screen	cartoon, animated
Alice Journalist			3D	woman	no motion	no	full body	partly	animated
Council of Coaches	adviser	adults	3D	woman, men	motion	no	upper body	full screen	animated
Lena	adviser	adults	2D	robot	no motion	no	full body	partly	cartoon
Sara	adviser		3D	woman	motion	hands	upper body		cartoon, animated
Echoes	coach, buddy	children	3D	boy	motion	arms, hands	full body	full screen	cartoon, animated
Coze	adviser	adults	2D	object	no motion	no	full body	partly	cartoon
Duolingo	adviser	adults, children	2D	animal	no motion	arms	full body	partly	cartoon, animated
Young Conker	coach	children, gamers	3D	animal	motion	arms, hands	full body	full screen, partly	cartoon, animated
Fragments	coach	gamers, adults	3D	men	motion	arms, hands	full body	partly	animated
Grasshopper	coach	adults	2D	animal	no motion	fixed positions	full body	partly	cartoon
Clumsy Ninja	coach	gamers, children	2D	men	no motion	no	partly	partly	cartoon
Mr. Wicker	coach	gamers	2D	animal	no motion	no	full body	partly, full screen	cartoon

Table 6: Part 1 of the ECA features resulted from the related work

communication input	BCT	theories	facial expressions
	reminder motivational message, reward, points, monitoring, social support, goal set	Goal-setting, Self-Determination	blinking, brows, mouth
multiple choice option	goal set, reminder	self-disclosure, social dialog	mouth, brows, eyes, face postition
speech	no		blinking, eyes, face postition, mouth
speech			
button	goal set		eyes, brows, mouth
button	information		mouth
button	reminder, hints, information		eyes, brows, blinking
button	information		breathing, mouth, eyes (big),
button			eyes, eyelidss, brows, lashes, mouth
text, button	information		blinking
	educational information		head nots, gaze, eyebrows, eyes, mouth
			eyes (big), brows, mouth, blinking
speech			
speech	information, goal set		
text	information		blinking
speech, visual			head nods, blinking, smile, eyes, brows
	information		eyes (big), gaze, mouth
text	information	pausing model	no
button	awards, path revealing		blinking, head (big), eyes,
speech, movement	praises, path revealing		blinking, head (big), eyes,
speech, movement	goal set, praises		eyes, brows, mouth, shape
button, tekst	goal set, praises		eyes, mouth
button	goal set, path revealing,		no
button	goal set, information		no

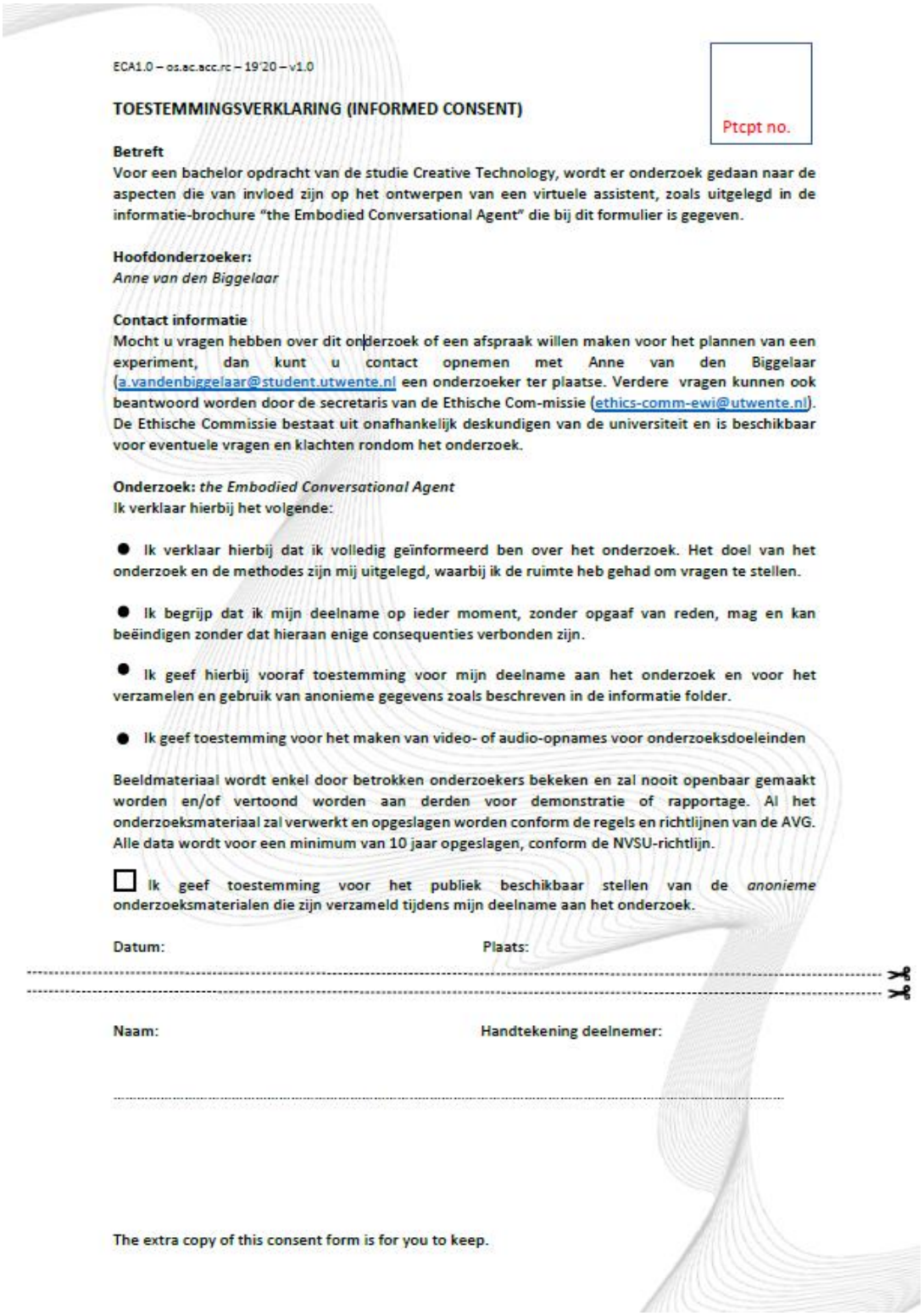
Table 7: Part 2 of the ECA features resulted from the related work

feedback	voice	feedback delivery	other
suggestions, reminder, notifaction, hints		textbox, picutres, videos	knowledge from experts
		textbox, pictures, speech	
	computer generated	speech, non-verbal	
hints, motivation, instructions		speech, non-verbal	begins with instruction on gameplay, communication agent dependent on politeness of user
instructions, praises	no	sound effects, textbox	
	voice female	speech, tekst box	
hints, advice	no	sound effects, non-verbal, textbox	(random) fixed animations in between, attributes to explain (lightbulp)
hints, tips, praises	no	textbox	seen as buddy: together follow the storyline
	computer generated	speech, non-verbal, expressions	asks user return questions
advice, humor	no	non-verbal	negative: didn't understand user, provides wrong information
advice, suggestions, humor	computer generated	non-verbal, verbal, textbox	
	computer generated	verbal, non-verbal	introduction by alice
		verbal, non-verbal	negative: lack deep understanding, lack emotion, generic, unmemorable
advice		speech	
advice	no	textbox	asks user return questions
return questions, advice	computer generated	speech, non-verbal	asks user return questions
		verbal, non-verbal, gaze, posture	body turns towards attention point
advice	no	textbox	
praises, rewards, information,	no	textbox, non-verbal	fixed animations in between
praises, tips, instructions, hints	voice boy	speech, visual	when in/out screen: set of flying eyes and particles
task provider, instructions, information, praises, hints	voice men	speech, non-verbal	when in/out screen: appear with particles, starts game by easy to solve task
task provider, instructions, praises,	no	non-verbal, sounds, visuals	easthetic focus of simplicity
praises, task provider, instructions	no	textbox	
task provider, instructions, information, praises	no	textbox, video	same style as game, sticks in ground until task is done, starts game by easy tasks, only full screen when explaining

Table 8: Part 3 of the ECA features resulted from the related work

B. Informed Consent Forms

B.1 Informed Consent form for Experts



ECA1.0 – os.ac.acc.rc – 19'20 – v1.0

TOESTEMMINGSVERKLARING (INFORMED CONSENT)

Ptcpt no.

Betreft
Voor een bachelor opdracht van de studie Creative Technology, wordt er onderzoek gedaan naar de aspecten die van invloed zijn op het ontwerpen van een virtuele assistent, zoals uitgelegd in de informatie-brochure "the Embodied Conversational Agent" die bij dit formulier is gegeven.

Hoofdonderzoeker:
Anne van den Biggelaar

Contact informatie
Mocht u vragen hebben over dit onderzoek of een afspraak willen maken voor het plannen van een experiment, dan kunt u contact opnemen met Anne van den Biggelaar (a.vandenbiggelaar@student.utwente.nl een onderzoeker ter plaatse. Verdere vragen kunnen ook beantwoord worden door de secretaris van de Ethische Com-missie (ethics-comm-ewi@utwente.nl). De Ethische Commissie bestaat uit onafhankelijk deskundigen van de universiteit en is beschikbaar voor eventuele vragen en klachten rondom het onderzoek.

Onderzoek: ***the Embodied Conversational Agent***
Ik verklaar hierbij het volgende:

- Ik verklaar hierbij dat ik volledig geïnformeerd ben over het onderzoek. Het doel van het onderzoek en de methodes zijn mij uitgelegd, waarbij ik de ruimte heb gehad om vragen te stellen.
- Ik begrijp dat ik mijn deelname op ieder moment, zonder opgaaf van reden, mag en kan beëindigen zonder dat hieraan enige consequenties verbonden zijn.
- Ik geef hierbij vooraf toestemming voor mijn deelname aan het onderzoek en voor het verzamelen en gebruik van anonieme gegevens zoals beschreven in de informatie folder.
- Ik geef toestemming voor het maken van video- of audio-opnames voor onderzoeksdoeleinden

Beeldmateriaal wordt enkel door betrokken onderzoekers bekeken en zal nooit openbaar gemaakt worden en/of vertoond worden aan derden voor demonstratie of rapportage. Al het onderzoeksmateriaal zal verwerkt en opgeslagen worden conform de regels en richtlijnen van de AVG. Alle data wordt voor een minimum van 10 jaar opgeslagen, conform de NVSU-richtlijn.

☐ Ik geef toestemming voor het publiek beschikbaar stellen van de *anonieme* onderzoeksmaterialen die zijn verzameld tijdens mijn deelname aan het onderzoek.

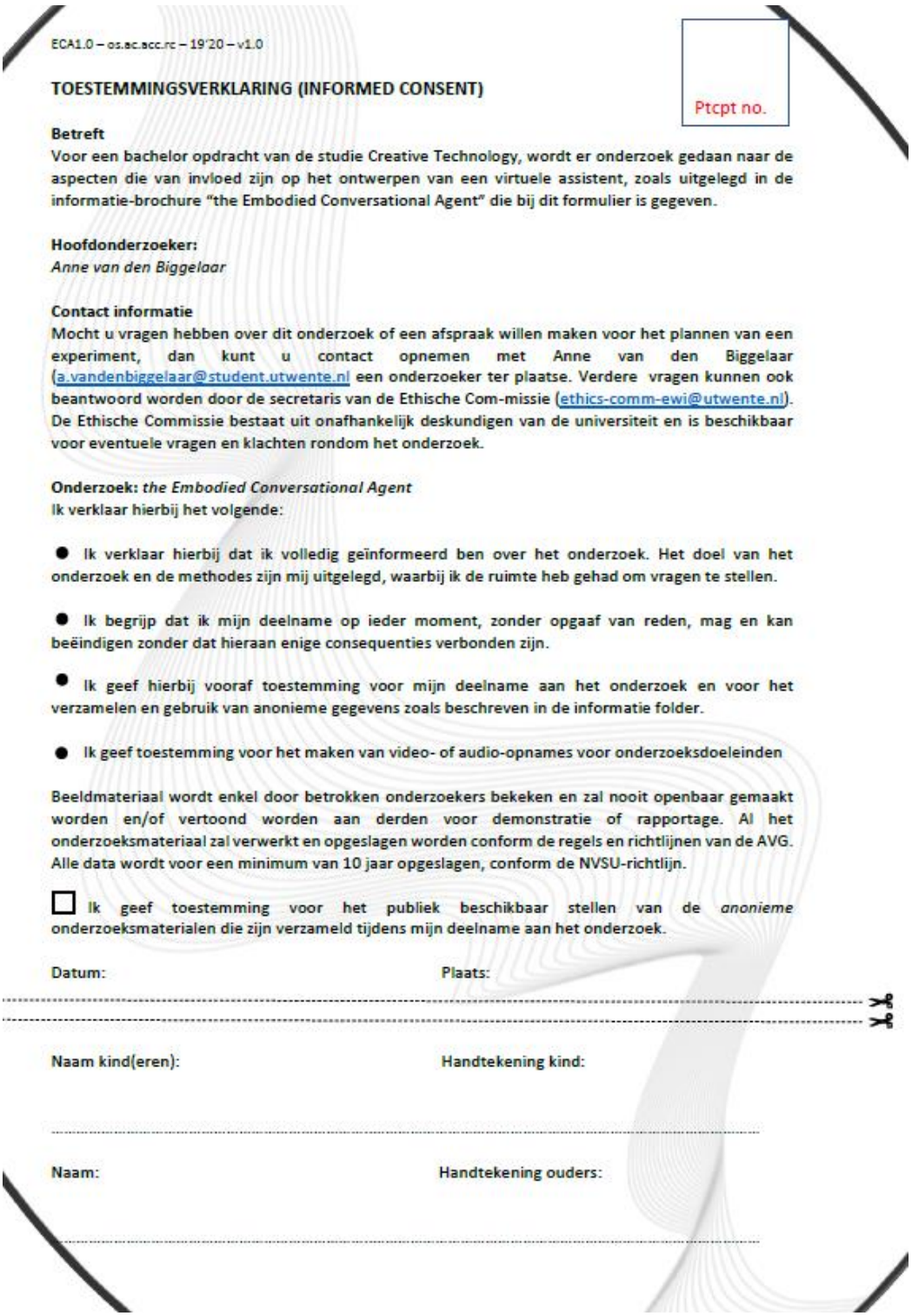
Datum: Plaats:

Naam: Handtekening deelnemer:

The extra copy of this consent form is for you to keep.

Figure 64: Informed consent form for Experts used for interviews and user tests

B.2 Informed Consent form for Children



ECA1.0 – os.ac.acc.rc – 19'20 – v1.0

Ptcpt no.

TOESTEMMINGSVERKLARING (INFORMED CONSENT)

Betreft
Voor een bachelor opdracht van de studie Creative Technology, wordt er onderzoek gedaan naar de aspecten die van invloed zijn op het ontwerpen van een virtuele assistent, zoals uitgelegd in de informatie-brochure "the Embodied Conversational Agent" die bij dit formulier is gegeven.

Hoofdonderzoeker:
Anne van den Biggelaar

Contact informatie
Mocht u vragen hebben over dit onderzoek of een afspraak willen maken voor het plannen van een experiment, dan kunt u contact opnemen met Anne van den Biggelaar (a.vandenbiggelaar@student.utwente.nl een onderzoeker ter plaatse. Verdere vragen kunnen ook beantwoord worden door de secretaris van de Ethische Com-missie (ethics-comm-ewi@utwente.nl). De Ethische Commissie bestaat uit onafhankelijk deskundigen van de universiteit en is beschikbaar voor eventuele vragen en klachten rondom het onderzoek.

Onderzoek: ***the Embodied Conversational Agent***
Ik verklaar hierbij het volgende:

- Ik verklaar hierbij dat ik volledig geïnformeerd ben over het onderzoek. Het doel van het onderzoek en de methodes zijn mij uitgelegd, waarbij ik de ruimte heb gehad om vragen te stellen.
- Ik begrijp dat ik mijn deelname op ieder moment, zonder opgaaf van reden, mag en kan beëindigen zonder dat hieraan enige consequenties verbonden zijn.
- Ik geef hierbij vooraf toestemming voor mijn deelname aan het onderzoek en voor het verzamelen en gebruik van anonieme gegevens zoals beschreven in de informatie folder.
- Ik geef toestemming voor het maken van video- of audio-opnames voor onderzoeksdoeleinden

Beeldmateriaal wordt enkel door betrokken onderzoekers bekeken en zal nooit openbaar gemaakt worden en/of vertoond worden aan derden voor demonstratie of rapportage. Al het onderzoeksmateriaal zal verwerkt en opgeslagen worden conform de regels en richtlijnen van de AVG. Alle data wordt voor een minimum van 10 jaar opgeslagen, conform de NVSU-richtlijn.

☐ Ik geef toestemming voor het publiek beschikbaar stellen van de *anonieme* onderzoeksmaterialen die zijn verzameld tijdens mijn deelname aan het onderzoek.

Datum: Plaats:

Naam kind(eren): Handtekening kind:

Naam: Handtekening ouders:

Figure 65: Informed consent form for Children used for interviews and user tests

C. Interview Questions

C.1 Physical therapy-related questions for the experts, during Context Analysis interviews

1. What techniques do you use to motivate the child?
2. How do you motivate the child to keep going during a therapy session?
3. What do you do when the child does not want to continue?
4. Are you present during the session?
5. Do you explain the exercises beforehand? In what way?
6. On what things do you pay attention during your explanation? How do you notice if the child understands you?
7. How do you make sure the child can learn and improve optimally?
8. In what way do you give feedback, and when?
9. How do you communicate it when the child needs to improve something?
10. What are important aspects to take into account during the sessions or when working together with children?
11. What attitude do you have towards the child?

C.2 Scenario questions for the experts, during Context Analysis

1. How do you envision the agent?
2. What are the different tasks that this agent will perform?
3. How does the agent behave? Think about expert, doctor, friend or brother.
4. Is the agent always present?
5. What are some requirements that the agents has to fulfil?
6. Is the agent helping during the exercise?

C.3 Scenario questions for the Children, during Context Analysis

1. Envision the scenario in your mind. What does the agent look like?
2. The agent comes towards you. What is the agent saying to you?
3. In what way is he coming towards you?
4. What is your relationship with the agent?
5. You have to perform the exercise. Is the agent helping you, or are you alone?
6. What are some unique or exciting things that this agent has?

C.4 Lo-Fi evaluations questions

1. Which three agents appeal to you the most?
2. Which three agents appeal to you the least?
3. Which three agents are most suitable to explain things to a child?
4. Which three agents are the best at being a playing buddy?
5. Which three agents feel the most trustworthy?

C.5 User Evaluation question

1. Overall, which robot appealed to you the most?
2. Overall, which robot appealed to you the least?
3. Overall, what did you prefer? A robot-like robot or a human-like robot?
4. Which robot did you find most enthusiastic?
5. Which robot did you find most playful?

6. Which robot would you consider to be a buddy?
7. Which robot would be best at giving you feedback?
8. Which robot would be best at giving you information

D. Robot Evaluation Form

	1	2	3	4	5	
	Menselijkheid					
onecht						natuurlijk
lijkend op een machine						lijkend op een mens
onbewust						heeft een bewustzijn
kunstmatig						levensecht
houterige bewegingen						vloeiende bewegingen
	0	0	0	0	0	0
	levendigheid					
dood						levend
stilstaand						levendig
mechanisch						organisch
daadloos						reagerend
kunstmatig						levensecht
passief (daadloos)						interactief (reagerend)
apathisch (lusteloos/sloom)						responsief (energiek)
	0	0	0	0	0	0
	sympathie					
afkeer						geliefd
onvriendelijk						vriendelijk
niet lief						lief
afschuwelijk						mooi
demotiverend						bemoedigend
	0	0	0	0	0	0

Table 9: Robot evaluation form, used during the user tests

E. Robot Evaluation Form

	modern				halfhalf				mechanical			
participants	Anthropomorph	Animacy	Likeability	total	Anthropomorph	Animacy	Likeability	total	Anthropomorph	Animacy	Likeability	total
1	19	15	22	56	16	19	20	55	17	19	21	57
2	13	13	18	44	12	14	16	42	13	16	21	50
3	11	8	17	36	16	15	17	48	16	20	21	57
4	12	16	20	48	14	15	15	44	15	15	21	51
5	15	17	20	52	17	19	21	57	18	20	22	60
average	14	13,8	19,4	47,2	15	16,4	17,8	49,2	15,8	18	21,2	55

Table 10: Results of the robot evaluation form