NAOfit - The personal trainer robot for overweight and obese children

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TA Summary (Please do not remove this part until the final submission): The project focuses on creating a NAO robot that will help overweight children engage in a workout routine. The robot will calculate the BMI based on provided height and weight, and will then select a workout program tailored to the child, with varying level of intensity and rest. Gestures will be used to show how to perform some exercises and lead the children to imitate them, giving also the correct timing.

Summary

Childhood obesity has become a global societal issue. One contributing factor to the issue is the lack of motivation to work out amongst children with weight problems. It is therefore important to explore methods to actively engage children in working out. In this research project, a personal trainer robot, NAOfit, has been developed to help motivate and engage children to work out. NAOfit selects the suitable workout program based on the child's BMI score and demonstrates the exercises and engages with the user through gestures and speech. The robot implements various exercises, gives instructions, shows the steps of the exercises and dances to actively engage users in the workout session. Numerous didactic techniques are implemented, from encouragements to non-verbal immediacy, to stimulate participation and motivation.

The paper is organized as follows: In the first section, *Foundation*, the problem statement is provided and relevant stakeholders and human factors principles are identified. In the *Interaction Design* section, the application context and design principles underlying the design of the robot are explained. In the *Implementation* section, details of the robot software are provided. In the *Evaluation* section, a study is described in which users were asked to evaluate the design features of the robot with regard to their motivation and engagement during the workout. The results showed that users who worked out with NAOfit experienced an increased level of fun, interest and motivation while performing the given exercises. The robots' social implementations shown through gestures and speech may have been a contributing factor to the results.

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Foundation

Problem statement

Problem Statement:

The World Health Organisation considers that an individual suffers from obesity when their Body Mass Index (BMI, body mass divided by the square of the body height) is greater or equal than 30kg/m². (Obesity and Overweight, 2021) Obesity is strongly correlated with many diseases and conditions, such as diabetes, some types of cancer and cardiovascular problems. This medical condition also affects children, with a 20.3% prevalence among 5- to 11-year-olds in the United States(Childhood Obesity Facts, 2021). In line with the given facts, this research will be focusing on children between age 6 and 12, fighting childhood obesity. Obesity is known to be caused by environmental factors (lifestyle of the parents, school policies, demographics), lifestyle adopted (physical activity, diet) and genetics. However, genetic factors account for less than 5% of childhood obesity cases (Anderson et al., 2006). Environmental factors are often tricky to deal with and are third party dependent, so, the usual approach is based on a better diet and workout programs. In Particular, workout programs are proven to restore cellular and cardiovascular homeostasis, improve body composition and activate metabolism (Tavares et al., 2015). This makes it a great resource for treating childhood obesity.

Farris et al. (2011) performed a study on workout programs for children between age 6 and 12. Even though significant reduction in body measures occurred at the end of the weight loss programs, 51% of the children left the study. This evidence shows that sustainability of the workout program is not often possible. This is due to a lack of motivation and/or supervising.

In this matter, social robots may potentially prevent this from happening. Consistency could be enhanced through rewards, such as gestures, dances and music when the workout is successfully done. Monitoring the exercises over time would enable the robot to offer a dynamic program. As a result, the workout becomes more progressive for the child, leading to a feasible, constant routine.

Problem scenario

Children with high BMI scores experience negative effects on their mental and physical health. They may experience phases of anxiety and depression. As a result, children fear going outside and playing with peers. Nevertheless, the underlying problem is the increased rate of child obesity. Children with a high BMI face health issues and their overall quality of life is negatively influenced. When children are overweight or obese, their physical health is at risk. Their blood pressure may be too high and their legs may start to hurt due to the excess weight. This hinders them to live a normal life, and, in return, will affect their mental health. The child will feel depressed due to lack of exercise and will experience anxiety when facing a social situation. The depression will make them even less social and wanting to stay inside the house most of the time.

Bystanders such as the parents of the child will also be negatively affected by this. The parent may become irritated from the child's behaviour. This can lead to irrational behaviour from the parents, such as forcing the child to go outside to play with others. Parents may even take it too far where they force the child to work out under parental supervision. The parents' behaviour will negatively influence the child. The child will feel forced and pressured to do the exercises which will negatively affect their opinions on working out. The child could experience trauma. This can impact their future behaviour where they will get flashbacks of the traumatic event, causing fear and anxiety when having to interact in similar environments.

Target Audience

The direct stakeholders are overweight and obese children bettwen the age of 6 and 12. Their weight problem is indicated through a high BMI, higher than the 95% of the percentile. This is based on data of height, weight. Children with a high BMI often struggle with their physical and mental health. These struggles influence their living conditions and their overall quality of life. The children experience low-confidence due to their low physical and mental health and underdeveloped social skills. Their physical and mental state hinders them to play outside and have social interactions with peers. The child might lack the ability to participate in school activities that involve physical performance. The targeted children play a main role in the problem of child obesity. Our solution will help motivate the children to workout and help them improve their social skills through human robot interaction. It will also help children lose weight to ultimately achieve a healthy BMI. As a result, children will have better physical and mental health, which will enable them to live a normal life. They will be able to do sports, play with other children outside and participate in school activities.

Other direct stakeholders are the parents/caretakers of the child. The parent/caretaker needs to purchase the tool and set it up so the child can use it. The parent/caretaker also needs to monitor the weight of the child for a specific amount of time. If the child is too young to use the tool on its own, the parent/caretaker needs to supervise the child while it is using the tool. The study from Wu et al. (2014) shows that children's cognitive and functional abilities are still in the developmental stage from age 3 to 8. The results suggest that parents need to supervise their children and apply a co-using approach when they are using digital technologies.

The indirect stakeholders are healthcare workers. They are the ones who need to suggest the tool as a solution for child obesity. More children with the same problems can be helped simultaneously because the exercises are performed at home.

Personas

Two different personas were created for the research design. Since the direct stakeholders are children with a high BMI who face weight issues between age 6-12, two types of personas were distinguished by age. Age is an important factor because children who are 6 to 8 years old need parental supervision when using technical tools and performing exercises. Children from age 9 to 12 can sufficiently work with technology and perform exercises without parental supervision. The characteristics of the two personas, Gabriel and Maria, are stated in Table 1.

Table 1

Persona 1 and 2 characteristics

Persona 1	Persona 2
Gabriel 	Maria 
User characteristics Age: 6 Sex: Male School: Primary school Characteristics: Fast learner, well behaved, good listener Feeling about robot: Excited	User characteristics Age: 12 Sex: Female School: Secondary school Characteristics: Shy, overthinker, good listener Feeling about robot: Curious
Goals or needs Be able to play outside with peers	Goals or needs Become more confident, social and being able to join ballet classes again
Problem Obesity and low fitness level	Problem Borderline obesity, low-self esteem and low fitness level

The first persona is Gabriel. Gabriel has a high BMI and categorized as obese. Due to his obesity, he encountered physical and mental problems. He often feels left out because of his looks and is out of breath very quickly when doing simple tasks. He wants to be able to play outside with other children. He is motivated to lose weight and improve his fitness. He is a good listener and a quick learner.

The second persona is Maria. Maria has a high BMI and is becoming obese. When she was 8 years old, she moved to the USA from Italy. She had to leave her old friends behind and gave up on her ballet classes. She was the new international kid at school and had an English tutor come to her home during her free time to improve her proficiency. She had no time to start ballet again and was too shy to make plans with peers. As a result, she stayed at home and watched TV instead.

At the start of the move, she was 130cm tall and had a normal weight of 38kg with a BMI of 22.5. Within 3 years, she became 145cm tall and gained 24 kilos, making her BMI go to 29.5. The fast weight gain impacted her mental health, making her feel even more left out and sad. She often becomes nostalgic where she thinks of her past ballet classes. She reflects how much fun she had and how social she was back then. She is motivated to lose weight so she can do ballet and get her self confidence back. However, she does not want to work out with other people and wants to do it at home where she feels comfortable.

Human-factors knowledge

Research has shown that several factors are associated with individuals exercising (Süssenbach et al., 2014). One factor is motivation. During a workout, motivation is enhanced by having a personal trainer present. Motivation is not only generated on an individual level. Motivation in a two party situation is an interactional phenomenon (ibid.). Previous research has shown that responsiveness and reactivity in interactions play an important role for understanding motivational processes. Furthermore, repair strategies like self-initiated and other-initiated repair are important for a reciprocal, goal-oriented achievement of interaction (ibid).

Past research demonstrated that an embodied robot system is able to support humans in cognitive and assistive tasks (ibid.). The study by Powers et al. (2007) found that robots had greater social impact on individuals than simple computer agents. In the study, the participants spend more time interacting with the robot compared to the agents.

Another proposed model for motivation that was investigated was sequential repair strategies. The analysis of human-guided workouts showed that the interaction between instructor and trainee is strongly sequential (Süssenbach et al., 2014) . Thus, this suggests that a robot system in the role of a fitness instructor needs a fine-grained and sequential model for a motivating interaction experience. The results show that the strategies have been succesfully acknowledged by the user. The sequential character of the advice (preparation followed by instruction, repair and finally feedback), allowed enough time for the robot to react (ibid.). As a result, it was able to put the instruction into beneficial practice.

Another result proved that working out with a robot led to better training effects, more intensive workouts and higher motivation (ibid). Therefore, on the basis of human-human interaction (HHI), a model for a robot's interactional conduct was developed. The proposed interactive, action–based motivation model for Human-robot interaction (HRI) is relevant for our research and helps to understand the underlying interactive nature of NAO.

Interaction Design

Design scenario

Maria is a 12-year old girl with a high BMI, indicating that she is obese. This impacts her physical and mental health negatively. Her parents expressed concerns because of her high blood pressure caused by her high BMI and her lack of social interaction with her peers. Maria has shown signs of depression and anxiety which further increased her BMI and antisocial behaviour. After her parents consulted a child healthcare specialist, the doctor recommended the humanoid NAOfit robot for Maria. The doctor explained that the robot acts as a personal trainer targeting overweight and obese children from age 6 to 12. The robot uses its gestures and speech to illustrate physical exercises for the child to replicate. It can therefore be seen as a personal trainer in robot form. After the consultation, Maria's parents buy the robot and introduce it to her at home. The parents explain the reason for buying the robot and set it up in her room. The parents first measure Marias height and weight so she can use the robot correctly.

After setting up the robot and turning it on, NAOfit is ready to interact with Maria. The robot introduces itself and asks for the user's name. The input data is the name “Maria” and the robot can identify the gender of the user through the given name. In this case, NAOfit identifies Maria as a female user. The second step is asking for the user's age. Maria says “ I am 12 years old”. This data is processed, and, based on the output, NAOfit commences the next command. In this case, Maria is “of age” and requires no parental supervision. After storing the users basic information, NAOfit starts the selection process. First, NAOfit asks Maria “How many times a week do you work out?”. This will give an indication of her current fitness level. After, NAOfit wants to know what Maria wants to achieve from the NAOfit program. The robot asks for her goals in order to provide the best program. To select the correct workout program, NAOfit asks for the user's weight and height. After NAOfit receives the input data, it calculates the user's BMI. In this scenario, NAOfit calculated a BMI score of 30.5. This score indicates that Maria is obese. Therefore, the “obese” workout program is chosen for Maria.

Maria stands in front of NAOfit to start the workout. The robot asks if she is ready, and once confirmed, it starts to explain the first step of the first exercise. NAOfit engages with Maria by explaining the steps through gestures and speech. Maria performs the steps with NAOfit so she can later perform the full exercise. After the robot shows the full exercise to Maria, she is asked to perform it under the robots countdown. In this case, Maria performs the exercise for 10 counts. Maria successfully completed the exercise and NAOfit gives praise to motivate her. The robot also plays music and performs a dance to show that she is done with the exercise. Maria is happy and excited to do the next exercise. After finishing all the program exercises for the day, NAOfit says “goodbye and see you tomorrow” and shuts down. Maria is left feeling happy and motivated to work with NAOfit again.

Application context

Physical environment:

The physical environment for this project would be limited to the houses of the customers. The Nao robot will be stationed at home. This has advantages, as this allows the NAO robot to always be charged, but it is also a safe and familiar environment for the obese children. The program involves image recognition. Therefore, it is important that the area is lit up. This is usually the case at home, as it has both windows as lights. The program also involves sound. Nao should be able to recognise the speech of the person that it is working with. This is another reason why the customer's house is a great environment for this project. Only potential downside is that some houses do not have a lot of space. Ideally, we want at least an area of about 1.5 meters by 1.5 meters.

Social environment

The robot is introduced as a workout buddy. The children who this product is targeted to should view NAO as their friend. This will help build trust. Its role as a workout buddy will be very clear as NAO reminds the children about their workout. It also has a built-in dialogue where it explains all of its features in a pleasant way. The audience will be limited to one person, as this product is designed for people who don’t want to work out with others.

Organizational environment

The robot is purchased by the parent/caretaker after healthcare referral. As NAO is expensive, parents have the choice to lease the robot. It can be good to lease NAO first to see if the child enjoys using it. When the Robot is malfunctioning, the children should call for their parents to solve the issue. They can in turn decide whether this is a problem to solve easily by e.g. charging the robot, or that they should seek contact with customer support. The robot does not need to be kept an eye on, as failures will not have negative consequences besides the children not being able to complete their workout.

Design ideas and principles

Social robot

Workout programs are often difficult to stick to, requiring high motivation in order to be successfully completed. This renders to be even more difficult to achieve in obese children. The study by McWhorter et al. (2003) on obese children workout programs found that verbal motivation greatly improves the childrens disposition to finish the exercises. Other types of resources such as upbeat music and dances are also important to enhance motivation in the child. This makes the NAO social robot a great choice for our task. NAO has a human-like, friendly physical appearance, elemental for the child to feel comfortable training with him. The size of the robot is also suited for the age range of the target children (6 to 12 years old). Additionally, NAO is able to take part in the verbal motivation scheme, as it is able to speak and process natural language. These capacities will make it able to receive data such as age and weight, which will be used in the dynamic program creation, and also giving explanations about the target exercises.

Lastly, NAO is also capable of moving parts of its body and making gestures, which will make it able to represent the different exercises to the kid, and also motivate him through choreographies and dances. Along with music playing during the exercises, these features make NAO the perfect social robot for keeping the child motivated.

Conversational interaction

The conversational approach used for the socially interactive robot will be in the form of dialogue. The robot will give verbal instructions so that the user can perform specific movements at some point. When the user interacts with the robot, speech recognition is used. First, the robot executes a command, for example, asking the user if he/she is ready to start the exercise program. The robot will wait for a response from the user which can either be a “yes” or a “no”. When the user responds with “yes” or “no”, the robot uses speech recognition to evaluate the given input. When it recognizes the command “yes”, the robot accepts and acknowledges the decision of the user for wanting to start the program. If the response is “no”, the robot accepts the user's decision through speech recognition. In this case, the identified decision is that the user is not ready to start the exercise program. Based on this, the robot will not start the program.

The conversational features of NAOfit are programmed to be applicable to children. It will have a friendly tone of voice, give advice, explain the exercises, give feedback and praise to the user through speech. The robot’s language is adapted to the language of a child in primary school. The vocabulary used is kept simple and does not contain difficult words. The sentences are kept precise and not too long so that children understand it better. After the user performs the exercise, the robot gives feedback. NAOfit will give positive affirmation when the user succeeds. This increases motivation and self-esteem amongst the user.

Non-verbal behavior

The robot uses non-verbal behaviour such as gestures. It moves its hands, arms, legs and head when interacting with the user. Gestures of the robot are essential when demonstrating the exercises for the user. The robot systematically demonstrates the necessary steps via gestures of the chosen exercise. The visualization and movement of the exercise makes it more comprehensive to the user and thus, easier to follow and perform it. For example, when a user needs to perform a squat, the robot will move its arms and legs to demonstrate the exercise. Based on the type of workout program, the tempo of the movements will vary. For users with a lower BMI, the movements will be quicker because the user's fitness level is high enough. People with higher BMIs will follow a slower tempo where the robot performs the movements of the exercises at a slower rate. The number of repetitions for exercises also varies per program. High BMI users will have to repeat less exercises than low BMI users. After each exercise, the robot demonstrates a dance and moves its hands to its mouth indicating that the user should remember to drink water. Additionally, the robot will stand in front of the user and move its head and fingers to give it a human-like feeling.

Personalization

NAOfit addresses children from age 6 to 12 who have high BMI levels. Age plays an important role because of the need for parental supervision. Users from age 6 to 8 are “not of age” and require parental supervision. Users between age 9 and 12 are “of age” and do not need parental supervision. For “not of age” users, NAOfit will ask them to get the parent/caretaker. Once both the supervisor and user are present in the room, they need to stand in front of NAOfit. NAOfit will use visual recognition to identify the number of users in the room. Once identified, NAOfit will continue with the interaction and proceed to the next step. Users “of age” can use NAOfit without supervision. The user can solely interact with the robot and the interactional flow is continued.

After categorizing the age of the user, NAOfit asks for the user's height and weight. NAOfit can choose from three different programs after calculating the users BMI. Workout program 1 is for children with an obese BMI score. Workout program 2 is for children with an overweight BMI score. Workout program 3 is for children with a normal BMI score and is used to keep children at a healthy weight. For each program, the same exercises are used but the speed and duration of the exercises vary. Workout program 1 will be slower and shorter because of the users lower fitness level. Program 2 is faster and longer than Program 1 because the user has a higher fitness level due to their lower BMI. Program 3 is the fastest and longest because the user has good fitness and endurance levels.

NAOfit acts as a friend and personal trainer to the user. The robot needs to act as a friend because the child cannot participate in social activities such as group sports or playtime with peers. Hence, the user will feel more comfortable and motivated when using a friendly robot.

The personal trainer aspect of the robot motivates, inspires and helps the user. By demonstrating personal workouts, NAOfit inspires the user. After the user performs the exercise, the robot gives feedback. NAOfit will give praise when the exercises were performed successfully and advice if not.

However, as robots are not humans, some users may fear it. In that case, the person will be approached calmly, and it will also try to have a sweet appearance.

Robot perception

The robot has various perception capabilities which include speech and visual recognition. For the NAOfit project, a strong emphasis will be on speech skills. This capability will help monitor the users performance and detect errors.

Reflection

For this project, the research ideas were presented to a group of theater students from Utrecht University. Additionally, a peer review session was held amongst AI students from the Vrije Universiteit Amsterdam. During the peer review session, each group presented their research project and a Q&A session took place after each presentation. The given feedback helped us analyse our design strategies and make improvements. After our use-case presentation, the theater students provided us with feedback. Additionally, a mood board was created that outlined three main categories for improvement. First, dialogue and interaction ideas for NAOfit were introduced. Second, physical appearance and gestures. Third, Speech/Voice. All the ideas were insightful and made us reconsider certain chosen factors. For example, we decided to fully implement a dance and the reminder for users to drink water after the exercise is complete into NAOfit.

Use case

Title	Work Out Session
Objective	Stimulate exercising by rewards (stories, music, dances) and supervise training to create dynamic programs
Actors	Child with high BMI (primary user and target of the work out program) Robot (initiates bonding process and starts the training) Parents/Caretaker (sets up the robot in room, tells child's weight and height to robot)
Precondition	The room is set up by the parents: they free the required space and place the robot. The child is brought in front of the robot. The robot is turned on.
Post-condition	The child completed the chosen work out in an enjoyable way.

Happy Flow	1. Parents/Caretaker free enough space in the room and place the robot in position. The program is started 2. Child interacts with the robot 3. Robot recognizes a user through speech and introduces itself. Robot remembers the progress of the child when they say their name. It then retrieves the stored data. The program is started for new users, and continued for familiar users. 3a. New training - Robot asks the child for the name and age 3a1 - Child is “of age” (8+ old): Robot recognises that child is of age and can ask for more information 3b. Continue training - Robot greets the child and asks for their weight and height 4. Robot chooses the training based on previous data of the child (grade of success of previous training, BMI, age). 5. Each exercise is explained by the robot via speech and gestures. Robot gives information about the duration of the exercise and starts the exercise for the given time. The robot verbally encourages the child, plays music and uses gestures. 5a- The exercise gets completed: A dance with upbeat music is performed while robot congratulates the child for completing the exercise. Robot also shows a “drinking gesture” and tells child not to forget to drink. Data is saved and taken into account for further work outs. 6- After completing the workout, the robot motivates and congratulates the child for working out. The session ends and the robot says goodbye to the child. 7- Data changes the duration and type of exercises over the sessions. Various programs are chosen based on a performance measure of the child via a fitness function. Goal is to achieve the last program with the child being able to fully perform it.

Alternative Flow completeness	**Alternative Flow age**
5. Each exercise is explained by the robot with mimics if possible. Robot gives information about the duration of the exercise and starts the exercise for the given time. Robot encourages the child and plays music. 5b- An exercise is not being done for a while at time *t:* This data is saved and taken into account for further work outs 6- After completing the workout, robot motivates and congratulates the child via speech. The session ends and the robot says goodbye to child 7- The data changes the duration and type of exercises over the sessions. Various programs are chosen based on the child's performance measure via a fitness function. Goal is for the child to achieve the last program and perform it	3. Robot recognizes a user via speech and introduces itself. Robot remembers the progress of the child by their name and the program is started for new users, and continued for a familiar users 3b. New training - Robot asks the child for name and age 3b1 - Child is “not of age” (6-7 old): Robot asks child to get parent/caretaker 3c. Continue training - Robot greets the child. Robot asks for parents to state height and weight of child 4. Robot chooses the training based on previous data of child (grade of success of previous training, BMI, age)

Requirements and claims

		Claims	
UC Step	**Requirement**	**Upside**	**Downside**

3	Robot introduces itself	Child does not need to make the first interactional step. Robot becomes personalised and a bond between the user and robot can be created	Child will be bored or is not interested in using it
3 a+b	Robot recognizes users through speech. It uses speech recognition to recognise the user's speech.	The robot can ask questions to the user and perform different actions, based on input.The robot remembers the progress of the active user through their personal data given via speech. The program continues where the user left off. For new users, it will start the program from the beginning	The user might overtrust the robot and start a normal conversation. They might get the feeling that the robot understands everything that the user says. The user might want to repeat previous exercises. Active users have to start from the beginning when using the robot with new users.
5	Robot demonstrates exercises via gestures	Robot ensures that child understands steps of exercises and can perform it	Difficult to measure if the child understood the exercise. Child might lie.
5 a+b	Child performs and completes exercise	Robot uses a countdown and gives instructions via speech to ensure that the child performs exercise. After the countdown, music is played and the robot dances and uses speech, initiating that the exercise is complete.	Child performs exercise alone and might forget necessary steps. Robot does not perform exercises with the child together. Child might not like the music and dance and is discouraged from working out further.

Interaction diagram

The interaction diagram can be found on Group 19- Interaction Diagram. As the interaction is inherently dynamic, the interaction flow could not be represented by a fixed visualization. The diagram consists of multiple flows. It starts with the 1) Introduction flow and then goes into the chosen 2) workout flow. There are three available workout flows. Each flow is chosen based on the calculated BMI of the user. Workout flow 1 is for obese children, workout flow 2 is for overweight children and workout flow 3 is for normal weight children.

Each workout flow consists of 3 sub workout flows. The sub flow entails the necessary steps for one exercise in the program. Each program contains 3 exercises, thus, 3 sub flows. After sub flow 1 (⅓) ends, a feedback flow is started. After the feedback flow ends, sub flow 2 (⅔) is started, etc. So once the user ends one exercise and receives feedback, the next exercise can commence. All workout programs use the same flow structures. After the last sub flow (3/3) and feedback flow, a termination flow is started. Once the termination flow has ended, the interaction flow is finished.

Implementation

NAOfit starts the interaction by introducing itself to the user and asking for the user's name and age. This data is then processed with Dialogflow entity. After the user states their age, NAOfit starts the second interactional step by following two of the given commands. If NAOfit identifies the user to be “not of age” it will ask the user to get a parent/caretaker. If the user is “of age”, it will ask for the user's height and weight. This information is checked with the Dialogflow entity. NAOfit continues the interaction by choosing the correct workout program through calculating the users BMI. BMI is calculated through a function by using the users height and weight data as input. Once the correct workout program is chosen, NAOfit continues the interaction by offering the user to follow one of the three exercises that have been implemented in the program. NAOfit will start the program when the user says he/she is ready to start. First, NAOfit starts to describe the steps of the exercise through gestures and speech. It explains the steps of the exercise and thanks to its ability to perform gestures, is able to show the user how to perform the exercise. After demonstrating each step and showing the complete exercise, the user should be ready to perform it. NAOfit uses a countdown for the user to follow when performing the exercise. After completing the exercise, the robot gives praise or advice to the user. During a full interaction, the steps are shown for each of the three exercises, followed by the last part each time. After the program is complete, the interaction ends. The robot says goodbye and the user feels motivated and better after performing the exercises with NAOfit.

For the incorporation of the design ideas, we created a file named ask_library.py. This library has functions that use Dialogflow which intends to convert a wide range of possible user answers into useful variables for our system: the user name, age, height, weight and yes or no answers. These library functions are then called in the state_machine.py file, whenever NAOfit needs to understand the user answer to a specific question (Appendix 1). Second, the interaction designs take the form of a finite-state machine (FSM) in which each state represents a conversational turn by the robot. In each state the FSM specifies what the robot should say, what gestures it should perform and how it should transition to the next state. Moreover, in those state machines we are using a combination of NAO’s functionalities, e.g. *Speech* and *Gestures*. This system of states avoids unexpected behaviour from NAO. Each state of the FSM usually represents a set of *Actions* that the robot is doing and a list of expected responses of the human interactor. The *Action* function is evaluated and its return value is used to determine which branch is taken. Tags are used in *Speech* commands to incorporate personal information (e.g. <name> can be used to add a child’s name to Speech commands). Methods are implemented to get Speech commands of the current state (*get_state*) to send to the robot and to perform state transitions (*update_state*). The transition to the next state is triggered based on the given response. This could be either: asking for the input again, or if the processing of the information worked correctly, the transition to a state with the follow-up questions. For the *Gestures*, Softbank Robotics’ Choregraphe was used. The program lets the robot move from one checkpoint to the other, having a smooth and intuitive movement flow as result of that, simulating a real person actually training. Once the exercises’ moves were implemented, dances were designed to cheer up users, especially when resting within the workout. With the help of Choreograph, we also added written text, making the robot talk and explain every passage of the physical activity in detail, attached to the flows. Finally, we put together all of the timeflows into a single and bigger one, representing the whole program from start to finish. After we repeated the same procedure for the second and harder workout option, the robot was ready to attend his first lesson as a training partner.

Evaluation

Research question

As stated in the problem statement, the main aim is to provide a tool that motivates children with high BMI levels to exercise and help them lose weight and improve their social skills through human-robot interaction. To achieve this goal, one needs to evaluate whether the implemented features of the robot contribute to the design objectives. For instance, whether the features improve the motivation and engagement experienced by the users compared to traditional workout practices (i.e. School sport). Therefore, the following research question has been formulated:

What is the effect of involving the personal trainer robot, NAOfit, on the users motivation and engagement level to perform the instructed exercises in the selected workout program?

It is hypothesised that a child friendly robot functioning as a workout buddy will increase the children's workout motivation by having implemented features such as dances, songs and easy vocabulary. It is also hypothesised that it increases the level of fun and interest throughout the workout session. The research question is planned to be addressed by running an experiment involving NAOfit and a group of participants. The desired target group are children with high BMI levels but can not be conducted on due to COVID. Therefore, the research will include student participants interacting with NAOfit. They will fill out a questionnaire about their experiences so we can analyse NAOfits effect on users motivation and engagement when they workout with it.

Method

Participants

Due to COVID, the experiment can not be conducted on the desired target group. As an alternative, the experiment will be carried out on a group of students who follow the Socially Intelligent Robotics course at the Vrije Universiteit Amsterdam (VU). The participants are male and female VU AI students, aged 20 to 30.

Ideally, the target audience would consist of male and female children between age 6 and 12. All children master the English language fluently and the group consists of equal gender distribution. Furthermore, all children have high BMI scores, indicating that they are either overweight or obese. The parents of the target audience consult a healthcare worker for advice on their child's weight problems. Before the consultation, parents are not familiar with the humanoid NAOfit robot.

Design

The participants are divided into two main groups. The groups are determined by the age of the child. The first group consists of male and female children from age 6 to 8. Group two are male and female children from age 9 to 12. Group one are "not of age" for using the robot independently and need parental supervision. The study from Wu et al. (2014)

suggests that parents need to supervise children aged 6 to 8 and apply a co-using approach when using digital technologies due to the childs developing cognitive abilities. The members of group two are "of age" and can use the robot independently. Both groups receive the same physical exercises and instructions to follow from NAOfit. There are three different programs which are determined by a child's BMI score. One program is for children with an obese BMI, the other programs is for children with an overweight BMI. Both programs contain the same exercises but differ in execution duration.

To test the impact of NAOfit on children's motivation, we introduce a control group. The control group consists of children from age 6 to 12 and are asked to perform the same exercises as in the workout programs of NAOfit. However, the children in this group need to perform the exercises without the robot. This will help test if the robot impacts the child's motivation for performing exercises.

Due to COVID, the experiment can not be carried out on children. The study will be adjusted to AI students at the VU. A group consisting of 6 students from the AI masters taking the Social Intelligence Robotics course at the VU will run the experiment. NAOfit will be set up by the group in the lab. The physical robot will be present and the code will be distributed to the group with the consent form, instruction sheet and questionnaire. The users have to connect the robot and follow its instructions. After each participant shares their personal information with NAOfit (name, age, height and weight), one out of the three workout programs will be chosen based on the user's BMI score.

The independent variable in this experimental design is the countdown of the selected workout program. The "obese" program entials a 10 second countdown for each exercise. The "overweight" program is increased to a 20 second countdown per exercise. The "normal" program has the longest countdown per exercise, consisting of 30 seconds.

The dependent variables are the motivation, interest, performance and the enjoyment of the participant during and after the physical therapy session, as well as the difficulty of following the exercises. The effectiveness of NAOfit is measured through the users BMI scores over time. The user's weight should be measured every week from the start of the program to keep the user's BMI up to date. However, for the experiment that will be conducted on students, the experiment should run for 15 minutes per participant. The participant should take 15 minutes to complete the NAOfit workout program for the day. The other dependent variables are measured through an online questionnaire (see Appendix A) that is filled by the participants.

Materials

Location

The experiment is carried out in the Interlab on the VU campus.

NAO robot

The 58cm tall humanoid NAO robot is used for the experiment. The robot has been programmed with the relevant Python libraries. Google's Dialog Flow is used for its speech and Softbank Robotics' Choregraphe for its gestures. The robot uses a function for selecting the workout program. The input data is the weight and height of the user and the output is the BMI score. The robot's introduction and responses to the workout program content are pre-programmed.

Computer
After using the robot, an online questionnaire is sent to the user. The questionnaire is completed on a computer.

Bathroom scale
Before using the robot, the participant needs to know their body weight in kilograms. To measure body weight, a bathroom scale is used. The participants need to remove their shoes and wear light clothes before stepping on the scale. The participant then steps on the scale. Once on the scale, they stand still for 5 seconds so their body weight can be measured. After measuring, the participants body weight appears on the screen of the bathroom scale. The given body weight in kilograms is then recorded on the individual's information form.

Wall height chart
Before using the robot, participants need to measure their height in centimeters. A height chart is set up and placed on the wall. Participants need to remove their shoes and stand straight against the wall next to the height chart. The height is measured by drawing a line with a pencil at the top of the participant's head. The height in centimeters where the line was drawn is then recorded on the individual's information form.

Questionnaire and information form
The questionnaire (Appendix A) is made in Google Forms. The information form which starts with a consent paragraph (Appendix B) is printed out and handed over to the participants. The questionnaire is filled in immediately after the interaction with the robot. The questionnaire consists of the following parts: general information of the participant (age, gender, previous experience with physical exercise) the user experience (difficulty of exercises, comments, etc.) and the ranking of motivation, interest, and enjoyment on a 1 to 5 scale (1: lowest and 5:highest rank).

Set-up
The experiment takes place in the Interlab at the VU. The study was set up by placing the robot on a flat surface in a standing position. The user then places themselves in front of the robot, facing it in a standing position. The robot needs to be connected to the default computer to run the software.

Procedure

The participants of the target group are recruited by healthcare workers working in clinics and doctor offices through a parent/caretaker. After a consultation session between the healthcare worker and parent/caretaker, a consent form is given to the parent/caretaker. The consent form outlines the goal of the research, procedure, privacy and contact information (Appendix B). It is explicitly mentioned that all of the data is to be processed anonymously. Within the form, the parent/caretaker has the choice to give permission for the child to participate in the research.

After the session, the parent/caretaker informs the target participant: the child, about the study. The research goal is explained to the participant before conducting the questionnaire. After getting approval from the participant and parent/caretaker through filling out the consent form, the experiment can proceed.

There are two conditions in the study. Condition one, “not of age”, requires parental supervision for participants of age 6 to 8. Condition two, “of age”, requires no parental supervision for participants of age 9 to 12. In order to execute the experiment, each participant is to be individually brought into a room. The room entails a bathroom scale, a height chart on the wall, and the NAO robot, positioned in the middle of the room. No one else is to be present in this room. The participants are given instructions on how to use the robot and are told to familiarise themselves with these.

Due to COVID, the original target group can not be used and a group of VU AI master students will participate instead. As the original target group are children, ethical implications may occur. More time will be needed to get the final approval for conducting the experiment on children. For the student group, the procedure for the experiment excludes the consultation session and no parental supervision is needed. The selected participants will fill out a consent form, receive an information sheet and a questionnaire to fill out at the end. They will receive the NAOfit code to set up the robot in the lab. After setting up, all participants are to be present in the lab and each one of them uses the robot individually. To start using NAOfit, the participant needs to stand in front of the robot and engage with it.

After a brief introduction, the robot asks for the user's name and age. Once the participants fulfill the required step, the robot will ask for weight and height data. On the instructions sheet, information is given on what commands to give in case the robot does not recognize it. The user must verbally share the information to NAOfit. After this step, the robot chooses one of the three workout programs based on the calculated BMI. The participants are asked to interact with the social robot and follow its narration and instructions. The robot uses gestures and speech to help demonstrate and instruct the exercises to the participants.

After 15 minutes, participants have completed the program and NAOfit shuts down automatically. If the user can not complete an exercise, NAOfit moves to the next exercise until the end of the program is reached. At the end, participants are to fill in the online questionnaire on a computer that is provided through a link.

Results

In this section, the results of the experiment are discussed. Due to COVID, the experiment could not be conducted on children. The study was therefore performed on fellow master AI students from group 2 at the VU. The materials for the experiment were shared with group 2. The code, consent form, instruction sheet and questionnaire were given to the group for them to run the experiment. After the group performed the study, the questionnaire (Appendix A) was filled out by the participants.

A summary of the questionnaire results can be found in Appendix C. The results show that the group consisted of 6 students, from age 20 to 30+. The gender ratio was equally distributed with 3 male and 3 female student participants.

Table 2

Questionnaire Results

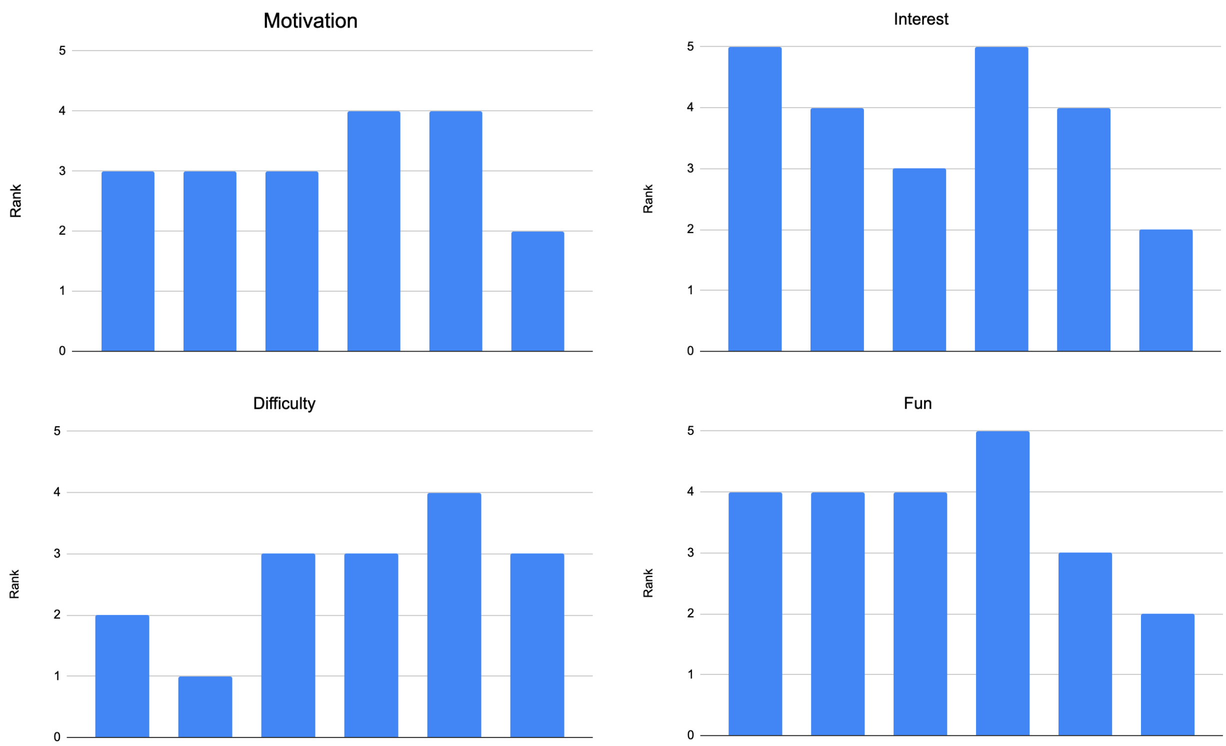
Participant	Age	Gender
1	20-25	Female
2	20-25	Male
3	20-25	Male
4	20-25	Male
5	20-25	Female
6	30 and older	Female

All participants used NAOfit for the first time and performed all the given exercises. Interest, motivation, fun, and difficulty levels for performing the exercises with NAOfit were ranked from 1, least, to, 5, most. Interest levels were highest, followed by fun and motivation. NAOfit was not easy but not very difficult to use.

Participants experienced a moderate difficulty level. Due to the small focus group, it is difficult to conclude general patterns and meaningful trends. However, the scores do give insight into how NAOfit is perceived by users and what factors need improvement for development.

Figure 1

Motivation, interest, fun and difficulty scores when performing exercises



The last question of the survey was an open question. It asked if any problems were encountered by the participants while using the robot. All 6 participants experienced issues and elaborated on it (Table 3). It showed that the main problem was the robot's speech recognition function.

The personal information asked by NAOfit had to be given by the user through speech. However, to choose a workout program, NAOfit needed to store the users information. The users experienced issues and needed to repeat their commands multiple times for NAOfit to fully recognize and store it. At the end, it did recognize all the users and the workout programs were selected eventually.

Table 3

Problems encountered when using NAOfit

Participant	Problem
1	Its speech recognition is not working properly; it just keeps on asking for the height, name and weight. Also, the stretching exercises with the arms in the end were a bit unclear what I had to do.
2	The robot could not recognise my name, could not recognise my age easily, and could not recognise my weight either. I would have liked it if the NAO participated more in the exercises, especially the plank and push ups. The arm stretches were a little unclear and it was difficult to perform neck stretches while still seeing the NAO robot.
3	I had some difficulties understanding my personal information, this took a while.
4	It did not understand my name or age for some time, it did not understand my height for a long time, and it did not understand my weight for an extremely long time (about 5 minutes)
5	Was not detecting responses
6	The voice detection quality of the robot was poor. Even the common names and numbers were not recognized(same for all the participants) which ruined the fun of having a conversation with the Robot.

Discussion

The outcome of the experiment shows how a humanoid robot may potentially help motivate children with high BMI scores to workout through human-robot interaction. By implementing social features into the robot, such as gestures and speech, the robot can help increase workout motivation amongst children. The robot may contribute to the motivation and engagement experienced by users when the exercises are demonstrated through gestures and speech. The results show that when non-verbal immediacies are implemented through gestures, users feel more comfortable and feel an increased motivation to continue the exercises in the program. Additionally, results show that participants were highly interested in working out while using NAOfit. The findings thus support the idea that the incorporation of immediacy into the robot aids the ability of the robot to serve as an effective training tool to demonstrate workouts, motivate and engage users to workout. Due to the given COVID experiment setting, the study was conducted on university students. Therefore, special consideration has to be taken when applying the experiment results to the investigated problem. As the study was not performed on children, specifically overweight and obese children, the validity of the results are therefore limited. The focus group only consisted of 6 participants and limited the conduction of a quantitative study. Hence, the study was restricted to a quality evaluation approach. A quantitative study would have introduced more objective data and helped in providing more insight on how the robot impacted the workout process. The experiment was conducted in a lab at the VU where more robots and students were present. As a result, complete silence was not feasible and background noise occurred. The results show that the main problem was speech recognition. A possible explanation could be the background noise that occurred while using NAOfit. This finding has potential consequences for the applicability in households. If the user's room is not noise-free, NAOfit might have issues with voice recognition.

Conclusion

The humanoid robot NAOfit used gestures and speech for social interactional purposes with users. The idea of NAOfit demonstrating exercises and explaining the steps has been successfully implemented. Many different types of gestures such as demonstrations and dances were used. Additionally, music and speech were implemented to help with robot user interaction as well. In order to keep user engagement high, we considered the perspective of children. Children prefer using NAOfit when they view the robot as a friend. Therefore, friendly applications were implemented in the robot. A motivational dance to show that the workout is complete was added to keep users engaged. By having friendly features, users had more fun and showed more interest in the robot. The interaction between the user and robot was also strongly sequential (Süssenbach et al., 2014). NAOfits sequential character including cues of instructions, repair and feedback, allowed the user to successfully acknowledge and engage with it. Overall, NAOfit shows promising results for motivating children to workout. As the experiment was conducted on a limited number of students, future research should experiment on a large group of children with weight issues. The study from Farris et al. (2011), stated that lack of motivation and supervision are the main factors affecting children's workout consistency. Based on our findings, we can say that NAOfit could be a possible solution for increasing workout motivation amongst children. Furthermore, as NAOfit gives instructions and supervises the users behaviour, it can further help children to sustain workout programs. Additionally, more research is needed to investigate if BMI calculations are the correct method for choosing the users workout program. Additionally, it is unknown for how long the user needs to workout with the robot to get a healthy BMI score. Also, other factors contribute to weight gain such as diet. A child might not be solely capable of losing weight by working out due to their diet. Future research can develop a better tool for choosing a workout program or also come up with a robot that considers the users lifestyle choices such as diets. It must also be said that NAOfit is not a replacement for a personal trainer. NAOfit aims to help children get motivated to workout and improve their social skills. After using NAOfit for a certain period of time, the child develops a better sense of self which enables them to play with other children outside.

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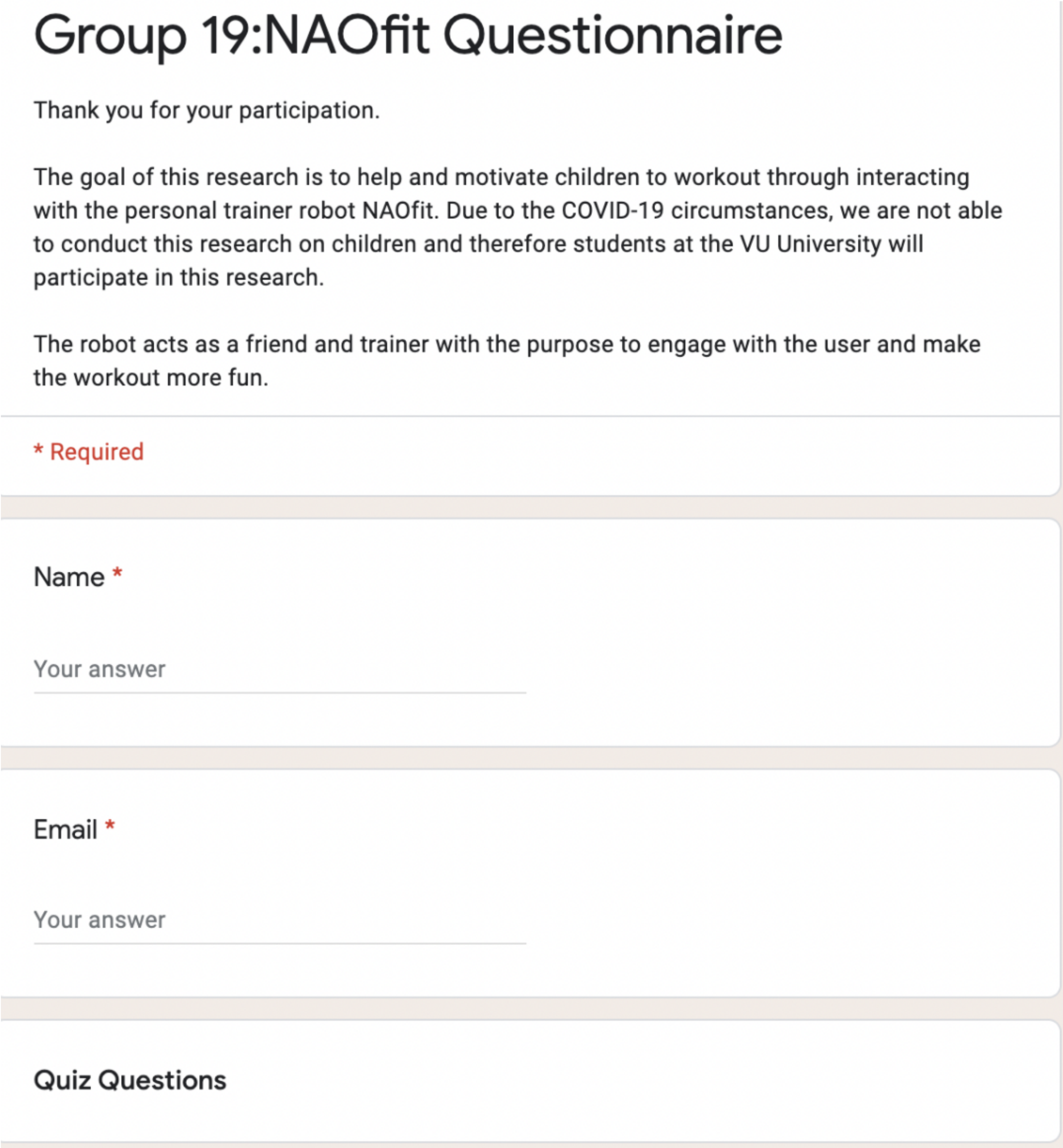
Appendices

Appendix 1: Dialogflow Intents

Intent name	Description	Type of anwser examples
ask_name	asks name	"My name is '*name*' "
ask_age	asks age	"I am '*age*' years old"
ask_height	asks height	"I am '*height*' meters tall"
ask_weight	asks weight	"My weight is '*weight*' kilos"
Yes_No_answer	asks confirmation	" '*Yes*' I am ready"; "I am '*not*' *ready*"

Appendix A: Questionnaire

https://docs.google.com/forms/d/1ThlHl7wjWS_3kVG8I6Yrj-M58W6BopY1sE0Wr7WURXw/prefill



Group 19:NAOfit Questionnaire

Thank you for your participation.

The goal of this research is to help and motivate children to workout through interacting with the personal trainer robot NAOfit. Due to the COVID-19 circumstances, we are not able to conduct this research on children and therefore students at the VU University will participate in this research.

The robot acts as a friend and trainer with the purpose to engage with the user and make the workout more fun.

* Required

Name *

Your answer

Email *

Your answer

Quiz Questions

How old are you?

- ◯ 20-25
- ◯ 25-30
- ◯ 30 and older

What is your gender?

- ◯ Male
- ◯ Female
- ◯ Other

Is this your first or second time performing the exercise? * 1 point

- ◯ Second
- ◯ First

Did you complete all the given exercises? * 1 point

- ☐ No
- ☐ Yes

How would you rate your motivation level when performing the exercises? *

	1	2	3	4	5	
Not motivated	◯	◯	◯	◯	◯	Very motivated

How would you rate your interest level when performing the exercises? *

	1	2	3	4	5	
Not interested	◯	◯	◯	◯	◯	Very interested

How would you rate how much fun you had when performing the exercises?

	1	2	3	4	5	
No fun	◯	◯	◯	◯	◯	Very fun

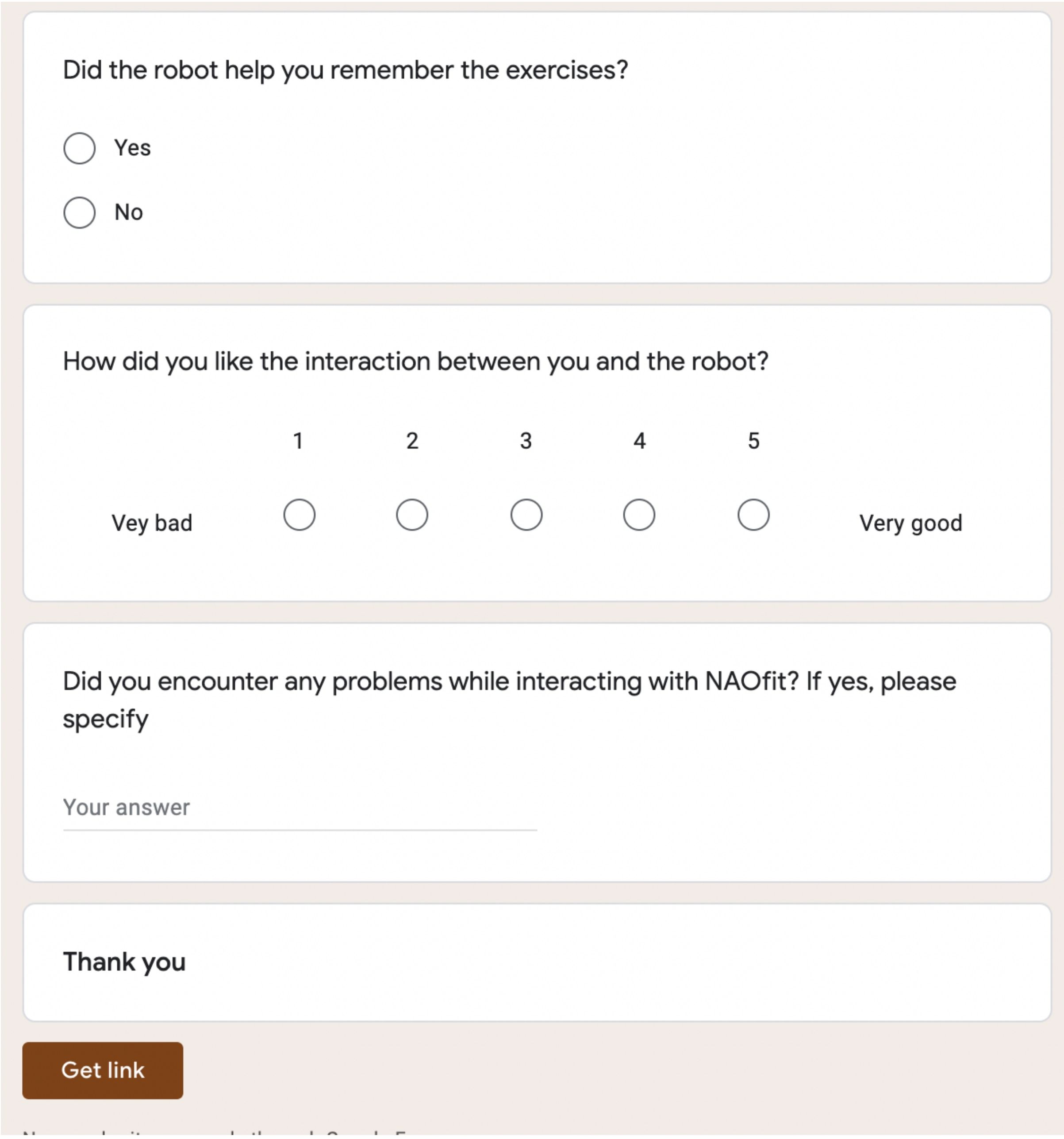
How difficult did you find the exercises?

	1	2	3	4	5	
Very easy	◯	◯	◯	◯	◯	Very hard

Do you have previous personal training workout experience?

◯ Yes

◯ No



Did the robot help you remember the exercises?

- ◯ Yes
- ◯ No

How did you like the interaction between you and the robot?

	1	2	3	4	5	
Vey bad	◯	◯	◯	◯	◯	Very good

Did you encounter any problems while interacting with NAOfit? If yes, please specify

Your answer

Thank you

Get link

Appendix B: Information and Consent form

Group 19 - NAOfit: Personal trainer robot

Participant number:

Goal of the research:
The goal of this research is to help and motivate children to workout through interacting with the personal trainer robot NAOfit. Due to the COVID-19 circumstances, we are not able to conduct this research on children and therefore students at the VU University will participate in this research.

Time of research:
The total time for each participant to complete the research is 15 minutes.

Privacy, anonymity and voluntary participation:
This research collects data from the participants by taking pictures of the exercises and collecting the answers in the questionnaire. All of the data will be saved anonymously. Moreover, we are not able to trace back any of the answers to you personally. You are not obligated to take part in this research. You are not obligated to answer any of the questions that you do not want to answer. If you consent to participate in this research, you will be able to end your participation at any moment without consequences. In this case all of your data will be removed.

Contact information:

Consent: I have read and understand the purposes of this research. I hereby consent to anonymously share the collected data with the researchers in this project.

Name participant, Date ____

Signature participant ____

Context

The trainer robot NAOfit aims to motivate children to workout and make the exercise fun and interactive. Imagine you are struggling with your weight and exercising so you consult a healthcare worker to help you. The healthcare worker suggests using NAOfit for you to become healthy again. After the consultation, you buy the robot and set it up in your room for you to use it.

Materials

To conduct the research, the participants need the following materials:

1. This documents including the consent form and simple instructions
2. NAO robot
3. Online questionnaire

Procedure

- On the research day, all 6 students will have to interact with NAOfit. They will fill out the consent form and have the instructions available.
- All participants will perform the given exercises that are included in the workout program,
- After the participants completed the workout program for the day, they will fill out the online questionnaire

Instructions

1. When NAOfit is turned on, stand in front of the robot.
    a. state *"yes*" to the question: *Are you ready for the workout?*
2. NAOfit will introduce itself and ask for the user name
    a. state your name in the form "*my name is [user name]"*
3. NAOfit will ask for your age
    a. state your age as *"my age is [user age]"*
4. NAOfit will ask for your height
    a. state your height as *"my height is [user height] centimeters"*
5. NAOfit will ask for your weight
    a. state your weight as *"my weight is [user weight] kilograms"*
6. If NAOfit does not understand a command, it will say *"I don't understand, can you repeat that"*
    a. Repeat what you previously said

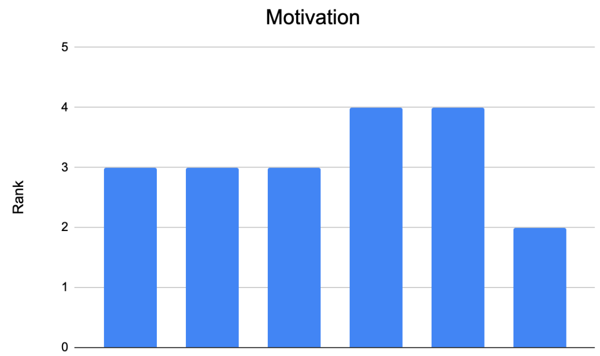
Appendix C: Questionnaire Results

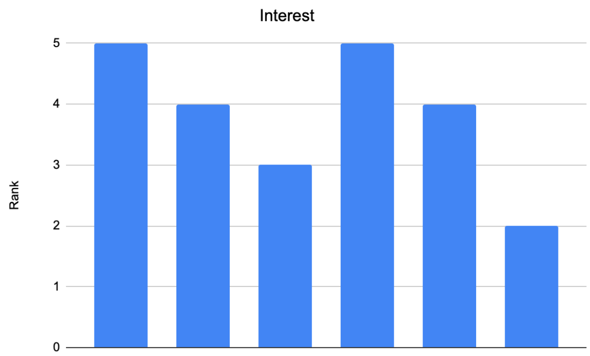
How old are you?	What is your gender?	Is this your first or second time performing the exercise?	Did you complete all the g
20-25	Female	First	Yes
20-25	Male	First	Yes
20-25	Male	First	Yes
20-25	Male	First	Yes
20-25	Female	First	Yes
30 and older	Female	First	Yes

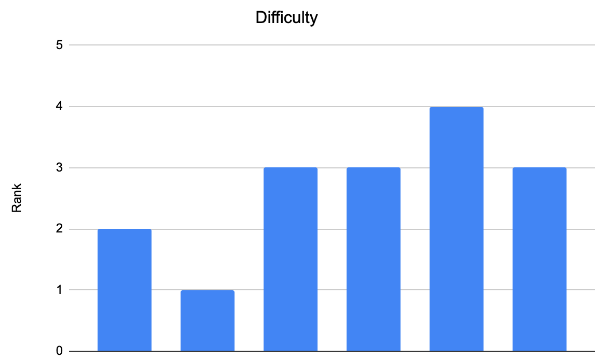
How would you rate your motivation level when performing the exercises?	How would you rate your interest level when performing the exercises?	How would you rate how much fun you had when performing the exercises?	How difficult did you find the exercises?
3	5	4	2
3	4	4	1
3	3	4	3
4	5	5	3
4	4	3	4
2	2	2	3

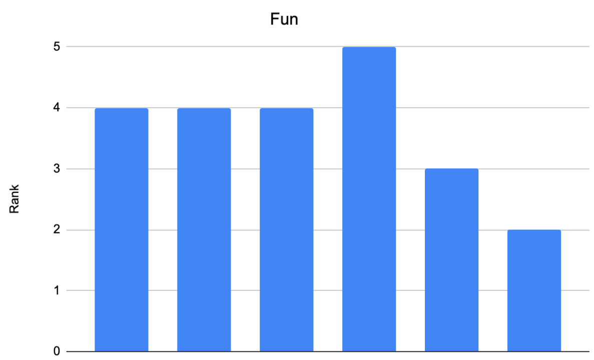
Do you have previous per	Did the robot help you ren	How did you like the intera	Did you encounter any problems while interacting with NAOfit? If yes, please specify
No	No	3	Its speech recognition is not working properly; it just keeps on asking for the height, name and weight. Also, the stretching exercises with the arms in the end were a bit unclear what I h
No	No	2	The robot could not recognise my name, could not recognise my age easily, and could not recognise my weight either. I would have liked it if the NAO participated more in the exercises
No	Yes	2	I had some difficulties understanding my personal information, this took a while.
Yes	Yes	5	It did not understand my name or age for some time, it did not understand my height for a long time, and it did not understand my weight for an extremely long time (about 5 minutes)
Yes	Yes	3	Was not detecting responses
No	Yes	2	The voice detection quality of the robot was poor. Even the common names and numbers were not recognized(same for all the participants) which ruined the fun of having a conversati

Appendix D: Visualized Results









Individual Project Summaries of Group Members

<Caroline Hallmann>

Instruction: *Provide a **brief summary of your contributions** to the design and development of your group's socially interactive robot, e.g., contributions to its design, implementation, the presentation, and the organization of your team (first paragraph).*

We came up with the research idea together and ran experiments. Caroline focused on writing the report and conducting research and implementing the interaction diagram. Julian and Max worked on the code and made sure that all the functions worked and that NAOfit had all the necessary features. Antonio worked on Dialogflow and with Choreograph. Francescco and Alonso also worked on implementing the correct features into the robot with Choreograph. Alonso also wrote the Problem definition, the use case table, and the social robot principle. During the lab sessions, we exchanged ideas and helped each other out. We were all present when we had to run Group 2s experiment. Max presented the use case to the theater group as well.

*Then briefly **reflect on your role as a team member** in your group (second paragraph). The questions about climate and process [here]() may help you write this second paragraph. We ask you to focus on the most important aspects in your reflection. Your project summary should fit on half a page.*

Caroline:
I focused a lot on the ideas and did research for the problem scenario, human factor knowledge and design scenario. I acknowledged the given feedback of my sections and improved the target audience part. For the design ideas and principles, I did research about the functionalities of the NAO robot. I wrote the paragraphs on conversation interaction, non-verbal behaviour, personalization and robot perception. For the presentation, I created the main goals, context, design scenario and target audience slides. I also included the use case tables and interaction graph on slides. After feedback, I wrote the Reflection section. In the paper, I also wrote the requirements and claims section. The interaction diagram was drawn by me and helped a lot with the implementation of commands for NAO. I first had multiple diagrams and then merged them together into one full diagram with multiple flows. For the implementation section I wrote the first two paragraphs, briefly introducing Dialogflow, the BMI function and describing the steps the robot takes in the interaction with the user. I wrote the methods section and created a questionnaire, consent form and instruction sheet for the experiment. I gave the printed consent and information sheet to Group 2 and sent them the questionnaire link digitally. After the experiment, we received the results and I wrote the results section. I created tables and graphs to show the results. Finally, I wrote the conclusion and discussion part based on the findings and previous mentioned information in the report. During the lab session, I helped the students who

worked with Dialogflow on what text to implement. The interaction diagram was very useful for that. I tested the robot and tried to identify issues and suggested ideas for improvements. The robot worked and the gestures and speech functions were applied correctly. I really enjoyed testing the robot and was happy that everything worked correctly at the end. My role in this project was to remind my teammates about the deadlines to have an efficient work dynamic. I mainly focused on the research idea and came up with a good interaction graph that helped my group members with programming and implementing the robot. I invested most of my time on the report and worked on it on a weekly basis and improved the parts based on the given feedback from the TAs. I experimented with the robot to see if the functions worked and to identify issues and come up with possible solutions. We all helped each other out to create a well functioning robot and it worked at the end. We had good communication and discussed issues and gave each other feedback. I think that my role as a writer and researcher was a good fit because I like to come up with ideas, do research and write academic papers. Due to my limited knowledge of coding, it made sense that I would focus on the report, experiment with the robot and come up with creative ideas.