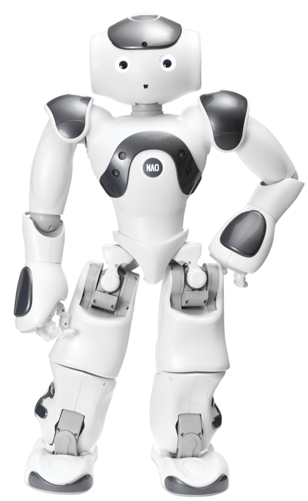
Design

Human-Robot Interaction

Radboud University

Motivating Movement in Children Through an Interactive Dancing Robot

Group 3



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1 The Problem

1.1 Exploring the Problem Space

The design of our project idea and its realisation began with a thorough exploration of the problem space. Physical inactivity among children is a growing issue with serious consequences for their health, development, and well-being. To identify the relevant causes of this issue, we took a closer look at the lives of children: trying to understand how they behave, what they enjoy, and the challenges they face when it comes to staying active. Thus, we created four distinct fictional personas that represent key features of the target user, capturing the variety of needs, interests, and experiences across different age groups. Using these personas, we uncovered various motivations and barriers that influence children's physical activity, and those informed our design decisions throughout the project.

Through our research, we identified four distinct archetypes that represent key segments of our target users; they are visualised in Appendix A. Jaehee, a five-year-old from South Korea, represents our youngest user segment – naturally energetic children who enjoy physical play but can be challenging to direct in structured activities. With a high level of physical activity and interests in playground activities and creative play, Jaehee exemplifies how even active children need engaging ways to channel their energy constructively.

Afonso, a nine-year-old from Portugal, embodies children who actively avoid physical activity. His lower activity level and preference for intellectual activities over PE class highlights a crucial challenge: how to engage children who prefer indoor, mentally stimulating occupations. His interest in science and building suggests potential for combining movement with learning and creative elements.

Lucas, an eleven-year-old from Brazil, represents children who struggle with confidence in physical activities. His self-consciousness about movement and preference for individual activities reveals the need for private practice opportunities and non-judgmental feedback. Despite his interest in dynamic content like superhero movies, his fear of making mistakes in front of others often holds him back from participating in physical activities.

Our last persona, Femke, a thirteen-year-old from the Netherlands, represents older children whose moderate activity level is influenced by social factors and digital media consumption. Her enjoyment of social activities like bowling with friends, while disliking structured obligations, indicates the importance of making physical activity feel more like entertainment than exercise.

Through these personas, we identified key trends and challenges in physical inactivity across different age groups. Younger children, like Jaehee, often need to sustain their natural love for play and movement. In middle childhood, as seen with Afonso and Lucas, engagement declines when activities feel irrelevant, uninteresting, or intimidating. In adolescence, represented by Femke, competing priorities and a focus on social interactions further reduce activity levels. This process helped us understand that any solution would need to be flexible enough to appeal to diverse preferences and capable of evolving alongside children's developmental stages.

These personas revealed several crucial insights that shaped our design approach. We recognized the need for flexibility in activity structure, from free play to guided movement. The importance of incorporating non-physical interests became apparent, as did the value of making exercise feel incidental rather than obligatory. Age-appropriate engagement strategies emerged as a key consideration, along with the need for building confidence through positive reinforcement.

These insights directly influenced our robot's design features, particularly the inclusion of both structured learning and freestyle dance options, the integration of educational elements, and the implementation of a supportive, non-judgmental feedback system. The personas helped us understand that the problem is not just about offering physical activity but also about tailoring it to children's interests and avoiding rigid, one-size-fits-all approaches. This understanding led us to develop a more adaptable and inclusive solution that could accommodate the diverse needs and preferences represented by our personas.

1.2 Defining the Problem

The insights gained from the discovery phase pointed us toward a central issue: the lack of a scalable, personalized, and engaging approach to motivate children to stay active. While traditional interventions often focus on structured physical activities, i.e., gym class in school, dance classes etc. these approaches fail to maintain interest because they do not adapt to children's individual preferences. Moreover, they lack the flexibility to integrate play, creativity, or social interaction – elements that are critical for engaging children across all age groups.

Refining the problem further, we recognized that a good solution should combine physical activity with elements that children already enjoy, such as music, creativity, or social engagement. Based on relevant literature, it was identified that robots successfully hold children's attention and curiosity [1], making them a suitable and easily available method to combine these three enjoyable aspects with movement in a way that is fun and personalized, such as dancing.

Thus, the problem we defined is as follows: **How can interactive robots be used to motivate children to engage in sustained physical activity, specifically through dance, in a way that is engaging, scalable, and adaptable to their different preferences?** This problem definition captures the progression of our understanding. From recognizing the challenges of physical inactivity to identifying a focused, innovative solution that addresses children's needs in a meaningful and personalized way.

2 The Solution

2.1 Exploring the Solution Space

After obtaining a better understanding of the problem and deciding on a type of solution to implement, we made use of a white board for brainstorming, to accumulate as many ideas as possible surrounding the main topics from our research. The brainstorming was separated into four components: robot-child interaction, dancing, dance evaluation system, and study design (see Appendix B). Note that these initially compiled ideas went through a lot of modifications based on the feedback collected afterwards and even due to technical limitations – more on that later in this report. Given the age of our target users, we could not directly involve them in the design process without arising ethical concerns, so we only discussed our ideas with legal adults.

Robot-child interaction. One of our first and main ideas was to draft a path that the interaction should follow. More specifically, the order and timing of asking certain questions and/or giving certain comments. Starting with an introduction message was a fairly obvious point and straightforward to implement, but some were less trivial, such as asking the child what action to perform, and whether to do this repeatedly and how often. The general idea was formulated rather quickly, where the main scenario was to be contained within a while loop, in which the child could choose whether to learn a dance move, simply dance together, or stop. For speech recognition, several models (i.e. Whisper, Google model, DeepSpeech) were already being considered and explored on a general level to check for compatibility and usability. For the generation of responses, we considered the usage of Large Language Models (LLM), such as GPT, but after consultation with our teacher (Dr. M.H. Vastenburg), a second idea was formed: only using GPT to pre-generated a set of sentences for each use-case, which still avoids repetitiveness in the robot's responses. Lastly, it was determined that the interaction should be conducted in a manner suitable for children. This implied no harsh or inappropriate language, and no complicated words and sentence structures.

Dancing. Dancing is the central part of our project. In order to maximise the motivation in children for movement, they must find the available dances appealing. Thus, we developed the idea of teaching them dance moves that are trendy amongst children, such as the dab or dances included in the video game Fortnite, which is popular among children. Furthermore, the dance moves should not be too complicated or too long in order to properly deal with a child's relatively short attention span [2]. Lastly, in order for the child to feel more in control, and not as though they are being forced to learn something, the idea for a freestyle dance option was coined. This was based on the argument that it does not necessarily have to be educational, as any activity is good.

Dance evaluation system. For increased level of interactivity, the robot should be able to analyze the child's performance and give appropriate feedback in a mainly positive manner.

For this, the initial idea was to have a reference to compare the child's body pose live. Then, based on a predetermined error threshold, the executed dance move would be evaluated as either sufficient or insufficient. If insufficient, the feedback should remain positive and should include the specific point(s) of the movement that were deemed insufficient. After an engaging discussion with another student who provided valuable feedback, we realised the comparison between intended and actual move was going to need a lot of experimentation: e.g., comparing joint locations vs angles between body parts, expecting a dab to the left but the child doing it to the right, identifying the body part that is positioned most "wrongly."

Study design. In order to effectively measure whether our implemented interactive dancing robot would have any effect on children's motivation to move, a control condition was required. Several ideas for control conditions were brought up, including the implementation of a less non-interactive version of the robot that some participants would interact with, or simply having them watch a video of the robot teaching them dances instead of engaging with it in the same physical space. When it came to assessing whether our set goal was reached, we were considering utilizing a questionnaire that would evaluate the participant's motivation for movement and enjoyment.

2.2 Converging to a Solution

With a range of possible solutions identified, work began on finding the best solution for each component. This process involved a few feedback sessions with peers, as well as some trial and error to identify and improve the most effective ideas.

Interaction with the child. In terms of interaction, we designed a flowchart (see Appendix C) including the possible interaction routes. After welcoming the child, the robot asks for their name, which is used later on to give the child a personalized experience. The robot gives a small fixed set of options for the child to choose from: learning a dance or dancing together, keeping it easy to follow. After every question the robot asks, the child can quit the session by simply saying so. During testing, we identified that sometimes it is hard to predict if the robot is listening or not, which is why we added a short beep sound before and after recording the user's audio, to avoid frustrating situations. After exploring several speech recognition models, we chose to run a version of OpenAI's Whisper model locally, because of its fast processing time, high accuracy and robustness — these features were crucial given our target user group: children who may not speak in proper full sentences or as audibly as adults and tend to not be very patient. To make the conversation with the robot seem as natural as possible, for a given situation, it gives slightly different responses with the same meaning. Although we initially had planned to use an LLM to generate them in real-time, we eventually chose to generate a set of possible responses using ChatGPT, as the results are the same, but without having to deal with added processing time and privacy concerns. Based on an insightful conversation with a mother of a young child, it was decided to take into account children's unpredictable behaviour and implement detecting whether there is any movement or auditory input. In the absence of such, the robot would ask whether the child wants to come back and continue dancing.

Dancing. To maximize children's motivation to dance, we decided to give the user options to choose from when it came to dances. We kept the number of dances short, both to avoid a long-winded listing of all available choices, and because we were working on a proof of concept. However, our implementation is easily extendable. The three dances we settled on are the dab, the air-guitar and the sprinkler: all relatively short, easy to learn for a child and most likely recognizable to the target audience as they feature in Fortnite. In the teaching mode, the robot shows one of the dances and monitors the child's performance to provide feedback afterwards. In the freestyle dancing mode, the robot performs the predefined dances and encourages the child to dance with it while also playing upbeat music.

Evaluation of child's performance. To evaluate the child's performance of the dances, their recorded body pose is analyzed using a python script. Although we had initially planned on using the robot's built-in camera, due to limitations in the communication between the robot and the device running the code, we had to make use of an external camera placed in front of the robot. In the end, we settled on taking images of the child to estimate the locations of their shoulders, elbows and wrists and calculate the angles between them, which are then compared to a reference to estimate an error. If the error value is below a certain threshold, the robot gives positive feedback, and otherwise it indicates which body part requires more attention next time. The phrasing of the feedback was modified and improved based on feedback we ourselves received about avoiding making it overly complex to parse and implement. Another useful tip we received and implemented was increasing the allowed margin of error after a few failed attempts — to ensure the child does not quit out of frustration.

Study design. To measure the interactive dancing robot's effect on the motivation of children to be active, we decided that after interacting with the robot, the participants of our study would fill in a questionnaire based on the Self Determination theory which provides insights into intrinsic motivation [3]. Besides that, the researchers present will take notes on the participants' behaviour during the experiment. A control group will be shown a video of a standard interaction by the same robot, which is edited such that the robot's questions are followed by a quiet time for the user's answer and then the robot resumes its activity assuming a positive response. This setup was chosen because it keeps all relevant variables unchanged except for the use of a physical robot and the interaction it entails. The control group fills in the same questionnaire and the results of both are compared per-group and grouped with our behavioural observations to help us answer our research question.

At the end of our design phase, to formalise the solution we arrived at and ensure all planned features have been considered and implemented according to their importance, we also generated a table of functional and non-functional requirements (see Appendix D).

References

[1] Jacq, A., Lemaignan, S., Garcia, F., Dillenbourg, P., and Paiva, A. Building successful long child-robot interactions in a learning context. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (2016), IEEE, pp. 239–246.

[2] Moyer, K. E. The Concept of Attention Spans in Children. *The Elementary School Journal 54*, 8 (Apr. 1954), 464–466. Publisher: The University of Chicago Press.

[3] Ryan, R. M., and Deci, E. L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist 55*, 1 (2000), 68–78. Place: US Publisher: American Psychological Association.

A User Personas

Figure 1: Four fictional user personas representing the target user.

B Brainstorm Board

Figure 2: A screenshot of our white board used for brainstorming ideas at the beginning of our project.

C Interaction Flowchart

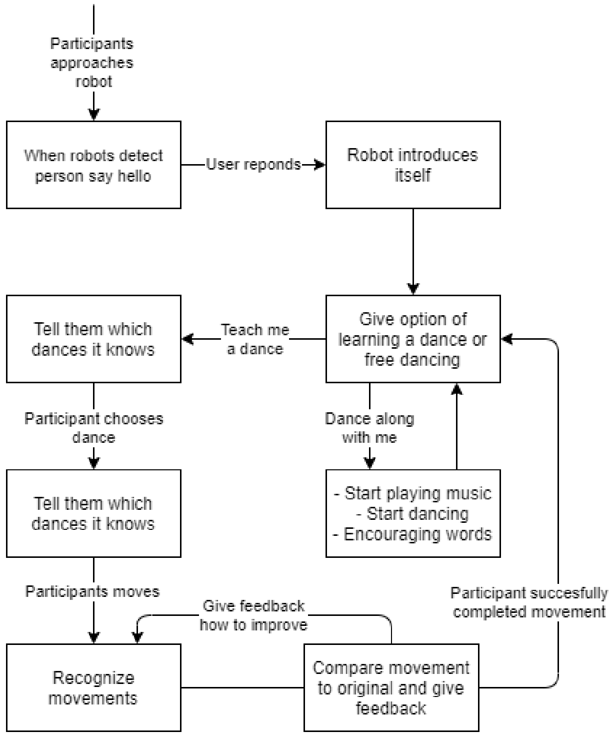

Figure 3: Flowchart visualising the desired interaction flow of the robot and the user.

D Functional and Non-functional Requirements

Functional and non-functional requirements for the system to be developed			
Requirement ID	Description	Priority	Type of requirement
1	The system will be able to interact with the user.	MUST HAVE	Functional
1.1	The system should have the capability to record auditory input.	MUST HAVE	Functional
1.1.1	The system must not store the recorded audio data after it has been used.	MUST HAVE	Non-functional
1.2	The system should have the capacity to produce speech.	MUST HAVE	Functional
1.3	If the user speaks to the system, it shall be able to respond adequately.	MUST HAVE	Functional
1.3.1	The system should have the capacity to understand the auditory input.	SHOULD HAVE	Functional
1.3.2	The system should respond with speech relavant to the user's prompt.	MUST HAVE	Functional
1.4	If the system is unprompted, it should initiate conversation when appropriate.	SHOULD HAVE	Functional
1.4.1	If the user is nearby, the system shall try to engage them into an interaction.	COULD HAVE	Functional
1.4.2	If there is no movement detected around, the system shall disengage.	SHOULD HAVE	Functional
1.5	The system shall produce speech in a fast manner that makes the conversation as natural as possible.	MUST HAVE	Non-functional
1.6	The system's interactions with the user must be appropriate, respectful and mindful of the age group.	MUST HAVE	Functional
1.7	The system should be able to react to unexpected circumstances adequately.	COULD HAVE	Functional
2	The system will be able to teach dancing moves.	MUST HAVE	Functional
2.1	The system will demonstrate dance moves when prompted by the user.	MUST HAVE	Functional
2.2	The system should have the necessary mechanical parts and software for the execution of dance moves.	MUST HAVE	Functional
2.3	If the user makes an attempt at a dance move, the system shall provide feedback on their performance.	MUST HAVE	Functional
2.3.1	The system should have the capability to compare the user's dance moves with a reference dance move.	MUST HAVE	Functional
2.3.1.1	The system should have an understanding of what a good dance move is.	MUST HAVE	Functional
2.3.1.2	The system should have the capacility to record visual input.	MUST HAVE	Functional
2.3.1.2.1	The system must not store the recorded visual data after it has been used.	MUST HAVE	Non-functional
2.3.2	If the user has a good performance on their executed dance move, the system should congratulate them.	MUST HAVE	Functional
2.3.3	If the user has a poor performance on their executed dance move, the system should provide them with constructive feedback.	SHOULD HAVE	Functional
2.4	The system's movements and activities should not put the user at risk.	MUST HAVE	Non-functional
3	The system will be able to perform dances without educational purpose.	SHOULD HAVE	Functional
3.1	If the user prefers to simply dance, the system should be able to join them in dancing without providing feedback.	SHOULD HAVE	Functional
3.2	If the user wishes to teach the system a dance move, the system should be able to copy it.	COULD HAVE	Functional
3.2.1	The system shall have the capability to record the user's movement.	COULD HAVE	Functional
3.2.2	The system shall have the capability to translate the user's movement into joint locations for the system's physical body.	WON'T HAVE	Functional