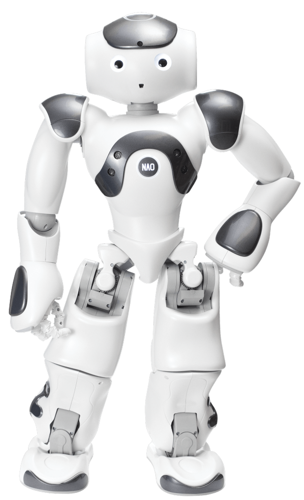
Background
Human-Robot Interaction

Radboud University

Motivating Movement in Children Through an Interactive Dancing Robot

Group 3



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1 Introduction

Physical activity is known to be crucial for children's health and development. A physically active lifestyle throughout teenage years correlates with improved bone and cardio-metabolic health, as well as with cardio-respiratory and muscular fitness [10]. Furthermore, evidence suggests that these health benefits may be sustained towards adulthood [10, 1]. In addition, recent research shows that an increased level of physical activity has a positive impact on cognitive development and mental health [6, 7].

Alarmingly, a recent study from 2020 by Guthold *et al.* shows a worrying trend. 81% of children aged 11-17 are insufficiently active, which poses significant long-term health risks [15]. The data was collected from school-based surveys originating from 146 different countries or territories resulting in a total of 1.6 million students. It is important to note that the data originates from 2016, implying that the COVID-19 pandemic did not impact these results in any way. Furthermore, the researchers did not find any clear patterns according to country income group, implying there is a broad decrease in children's activity level, regardless of their and their countries' socioeconomic status. The decrease in physical activity among children is further substantiated by a research on Finnish children (7-15 years old), where a clear decrease in physical activity was observed between 2020 and 2022 [20]. The researchers noted that the COVID-19 pandemic further exacerbated this negative trend. A systematic review on the implications of the COVID-19 pandemic on physical activity in children (¡18 years old) also shows a clear reduction in the level of physical activity [31]. No research has yet been conducted on the extent to which the reduction of physical activity during the pandemic actually carried on in post-pandemic times. Nevertheless, it is clear that a significant decrease of physical activity in children exists [15, 20].

It is therefore of utmost importance to scale up known effective intervention programs to increase activity in children and prevent their hurdled development. Additionally, it is highly relevant to explore potential novel solutions that could potentially improve children's motivation to be active. In this paper, we explore one such cutting-edge intervention methodology, namely designing an interactive robot that teaches children dance moves or dances together with them to music, depending on the child's desire.

Previous studies have shown that interactive approaches involving dancing can effectively increase the activity level in children [12]. Furthermore, research into robot-assisted teaching has shown that it can help increase the students' interest and motivation for a certain task [21], suggesting that an interactive dancing robot may improve the students' motivation for movement specifically. Further details on how and why robots are useful for improving movement motivation in children will be discussed in section 2.

No research has yet been conducted on increasing motivation of physical activity in children through the use of an interactive dancing robot. This implies the need for the creation of a novel robot implementation in order to meet the goals of this project.

2 Background

2.1 Increasing physical activity in children

Given the significance of physical activity for the health and development of children, adolescents and teens, a large number of intervention studies has already been conducted in search for effective strategies of increasing activity levels. Some research focuses on the child care settings as evidence has been shown of correlation between preschool attendance and the child's physical activity [18]. For instance, studies have examined the added value of additional 30 minutes of outdoor time [2], allocating time for jumping and hopping in the school day [35], and providing short 10 minute activity lessons as part of the curriculum every week [5]. All aforementioned works indicate that regularly provided and structured physical activity in preschool can increase the amount and intensity of physical activity that children receive. Similar intervention with the inclusion of activity sessions throughout the week has been attempted also at schools with children aged 11 and above, but it is usually complemented with lessons on healthy eating and exercise, and often involve computer-based health sessions [29, 3, 30, 36].

Dancing in particular has received some attention as an intervention method to increase level of activity, given that it is commonly rated as enjoyable and there is a strong correlation between enjoyment and the intrinsic desire and motivation to maintain an activity [11]. Studies focusing on dancing usually provide the participants with at least one hour of dancing classes a week, and report that dancing provides an equal, if not greater effect, on numerous physical health outcome measures when compared to other forms of exercise [34, 24, 17]. In contrast to previous work, by introducing a robot in the intervention scheme we aim to provide a more freely available solution, where the availability of a tutor and a dancing room for a class of students no longer constrain the frequency, location and genre of dancing performed.

Robots have been utilised previously to encourage physical activity, although the focus of such research falls mainly on older adults. For example, the humanoid robot NAO used in our study has also been used successfully as an exercise coach of the elderly [14]. One work with toddler participants makes use of robots in a play room and reports increased activity in the presence of an active robot [26], and another work shows that a humanoid robot increases the motivation of hospitalized children aged 3-15 to perform different activities - one of which is dancing alongside the robot to music [27]. To our knowledge, there is no study conducted with children where a robot encourages movement through teaching dance moves, with existing work involving mainly adults or investigating the impact of the robot on the children's social interaction [22] or studying long-term robot-child interaction [33].

2.2 Robots as dancing tutors

Although the effect of robots as dancing tutors on children's activity levels has not been investigated, there have been attempts to integrate robotics and AI into dance education, in order to open new pathways for enhancing skill acquisition and engagement. AI-driven systems, such as DancingInside [23], leverage advanced pose estimation technologies to provide feedback on technical accuracy while collaborating with human tutors who offer guidance on expressive qualities like emotion and groove. Similarly, Liu-Jie *et al.* [38] developed a dance skills teaching, evaluation, and visual feedback (DSTEVF) system based on AI, which was applied in a classroom setting. Using motion detection, the system provided visual feedback that helped students refine their dance techniques. The study demonstrated that the DSTEVF system significantly improved students' dance skills and self-efficacy. However, it had no significant effect on motivation, suggesting that additional strategies may be necessary to sustain student engagement. Furthermore, the findings revealed that students with higher levels of pre-existing motivation and self-efficacy benefited more from the system than those with lower levels, highlighting the importance of individual differences in maximizing the potential of AI tools.

Robots have also shown significant promise in asistancing with physical activities and facilitating social engagement through dance education. For example, Ros *et al.* [32] programmed NAO to teach dance sequences to children. By mimicking human teaching methods, the robot initially succeeded in maintaining high levels of engagement among children. However, the study identified challenges such as declining participation over time due to the diminishing novelty of the robot and task repetitiveness. These findings emphasize the potential of child-robot interaction for task instruction while underscoring the need for strategies to sustain long-term engagement.

Another notable advancement in robot-assisted dance education is the work of Paez Granados *et al.* [28], who introduced a dance teaching robot employing physical human–robot interaction (pHRI). Their system used adaptive impedance control and progressive teaching methodologies to guide novices in learning social dance figures. By dynamically adjusting the robot's behavior based on cumulative performance scoring, the approach provided tailored physical guidance alongside cognitive feedback. This combination fostered improved learning outcomes and highlighted the robot's ability to bridge the gap between technical learning and interactive engagement.

Building on the potential of robotics in dance, Tiffany L. Chen *et al.* [8] explored the application of robots in partner dance-based exercises aimed at promoting healthy aging among older adults. Their study investigated the acceptance of a human-scale wheeled robot with arms, designed to perform the Partnered Stepping Task (PST). The results demonstrated that older adults successfully engaged with the robot, finding it useful, easy to use, and enjoyable. Furthermore, perceptions of the robot's ease of use improved after participants completed the PST, indicating growing familiarity and acceptance.

2.3 Robots in children-interaction

Robots have proven to be valuable tools in child-robot interactions across various domains, demonstrating their ability to educate, support and motivate children. In education, there has been a significant amount of research into different ways to apply robots [4]. For example, Lopez-Caudana *et al.* [25] investigated the use of the Nao robot in elementary school Physical Education classes. The study demonstrated that lessons assisted by the robot significantly improved student's attention span and motivation compared to traditional learning methods. By incorporating robotic guidance, children were more focused, enjoyed the lessons more and developed a better understanding of maintaining a healthy lifestyle, which is important for preventing health conditions. Similarly, an experiment conducted in a Japanese kindergarten explored children's free interaction with the robot Pepper [37]. During this experiment, children aged 3 to 5 engaged with the robot through activities like dancing and playing, showing a natural curiosity and enthusiasm for interaction. Robots have also been used effectively to enhance personalized learning through affective interaction [13]. Gordon *et al.* developed a social robot tutor that personalized its motivational strategies based on children's emotional responses. In a study with preschoolers learning a second language, it led to improved learning and a greater emotional engagement compared to a non-personalized robot. This demonstrates the possible prospects of robots in education.

Robots have also found valuable applications in healthcare. A study evaluated the use of a personal robot to provide diabetes self-management education to children with type-1 diabetes [16]. The robot personalized the interactions based on the self-determination theory, focusing on the need for competence, relatedness and autonomy. Results showed that children interacting with this robot demonstrated greater pleasure and motivation, as well as an improved knowledge of their condition. In therapeutic contexts, robots like KASPAR have been used to support children with Autism Spectrum Disorder (ASD). KASPAR, a child-like humanoid robot, provides interactive interventions to help children develop social skills. These skills include understanding emotions and engaging in joint attention tasks. Studies have shown that children with ASD are more willing to interact with KASPAR than with humans, making it an effective tool for encouraging social engagement and improving communication skills [9, 19].

Given the increased motivation, engagement and attention levels achieved in children with the help of robots in the reviewed literature, in this research we also design child-robot interaction that aims to be as natural and personalized as possible in order to encourage movement in children.

3 Project Goal

There is a clear need to address declining physical activity levels among children, with 81% being insufficiently active [15]. While various interventions have been attempted, including structured physical activities and dancing programs, these often face limitations in availability, personalization, and sustained engagement. Although robots have shown promise in educational and therapeutic contexts with children, and as dancing teachers for adults, there remains a gap in understanding how robot-human interaction could be used specifically to motivate children's physical activity through dance.

The primary goal of this project is to investigate how human-robot interaction influences children's motivation for physical activity through an interactive dancing experience. Specifically, the aim is to understand whether and how the interactive presence of a humanoid robot (NAO) affects children's engagement and motivation to participate in physical activity, compared to a non-interactive video format of the same robot demonstrating dance moves. This research addresses several key opportunities identified in the background:

- Unlike traditional dance interventions that require dedicated teachers and facilities, a robotic solution could provide more accessible and flexible opportunities for physical activity.

- While robots have proven effective in child-robot interaction for education and therapy, their potential for promoting physical activity through dance remains unexplored.

- Previous research on robot dance teachers has primarily focused on adults or technical dance skill acquisition, rather than children's motivation for movement.

Building on that work, this project aims to answer the question "How does the interactive presence of a robot influence children's motivation for physical activity compared to non-interactive video demonstrations?". This research thus aims to increase the understanding of how the social and interactive capabilities of robots can be leveraged to address the critical challenge of insufficient physical activity among children.The hypothesis is that direct interaction with the robot will lead to higher engagement and motivation compared to video demonstrations, due to the personalized and responsive nature of the interaction.

Furthermore, this project has several contributions to existing HRI research. Firstly, it develops and evaluates a novel paradigm for child-robot dance interaction focused on promoting physical activity rather than skill acquisition. Secondly, it investigates the specific impact of physical robot presence and interactivity on children's movement motivation, providing insights into the value of embodiment in child-robot interaction. Thirdly, it extends existing work on robot dance teaching by adapting it for children and focusing on motivation rather than technical performance. Lastly, it explores how principles from successful child-robot interaction in educational and therapeutic contexts can be applied to promoting physical activity.

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