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Adaptive human–robot interaction in sensorimotor task instruction: From human to robot dance tutors

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HIGHLIGHTS

- Human–human interaction has been studied to identify teaching methodologies.
- We implemented a robotic system capable of instructing dance sequences to children.
- We present an involvement measure based on the combination of behavioral cues.
- The detailed observational analysis revealed high levels of children involvement.
- Results show a need for further research in social adaptation with robots over time.

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ABSTRACT

We explore the potential for humanoid robots to interact with children in a dance activity. In this context, the robot plays the role of an instructor to guide the child through several dance moves to learn a dance phrase. We participated in 30 dance sessions in schools to study human–human interaction between children and a human dance teacher, and to identify the applied methodologies. Based on the strategies observed, both social and task-dependent, we implemented a robotic system capable of autonomously instructing dance sequences to children while displaying basic social cues to engage the child in the task. Experiments were performed in a hospital with the Nao robot interacting with 12 children through multiple encounters, when possible (18 sessions, 236 min). Observational analysis through video recordings and survey evaluations were used to assess the quality of interaction. Moreover, we introduce an involvement measure based on the aggregation of observed behavioral cues to assess the level of interest in the interaction through time. The analysis revealed high levels of involvement, while highlighting the need for further research into social engagement and adaptation with robots over repeated sessions.

1. Introduction

Human–robot interaction (HRI) has gained attention in the past years, not only to benefit people from the aid of a robotic system in daily activities, but also as a tool to study social development (ability to interact with others). Extensive surveys can be found in [1,2].

A particular area of HRI research concerns children–robot interaction in therapeutic and edutainment settings. Nowadays children are very close to technology in their everyday activities. However, the language, appearance, environment settings, motivational resources, evaluation tools, etc., used with children greatly vary from those used when interacting with adults [3]. Therefore, devoting research in this area has become crucial.

This research explores the potential for robots to interact with children around a task instruction in an edutainment setting. The ultimate goal is to provide an alternative tool to promote physical activity among young people, where the robot plays the role of a tutor in the first stages, and eventually, as a peer. In this paper we pursue the following sub-goals: (i) study the transfer of human behavior to robotic systems, (ii) implementation of a robotic system with a minimum set of capabilities to autonomously perform the task (except for perception); and (iii) evaluation of such an attempt in a real setting.

In order to study child–robot interaction we have focused on a dance activity. Dance is considered a fun activity that allows children to easily engage [4], probably due to the involvement of body movement during the activity which in turn increases

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enjoyment [5]. But more importantly it (i) stimulates physical movement, which is essential for the development of fundamental motor skills; (ii) enhances the development of social skills, such as cooperation, coordination, sharing ideas, sharing physical space, accepting individual differences; (iii) increases communication skills; and (iv) promotes the development of creativity and spontaneity [6,7]. Considered an important educational source, dance is also promoted at schools as part of their curricula (e.g. in England it is part of the Curriculum for England in Physical Education [8]). Dance is not only a good practice for children, but for people in any age range, including elderly people where it has demonstrated to have physical and psychological benefits [9].

Moreover, from the HRI point of view, dance is an activity where embodiment is required. While verbal communication is indeed a valuable source of information, it is not crucial. The main means of communication is the body itself making it natural to interact with a robot. Therefore, we believe that sharing the space with a robot is a motivational resource that aids the user to effectively engage in the task as opposed to a virtual dancer in a screen.

The remaining of this paper is organized as follows. Section 2 summarizes research related to the work presented here. Section 3 reports the observations carried out to study dance sessions with children in schools. Based on these, the design and implementation of a dance tutor robot are introduced in Section 4. The experiments' procedure and results are described in Section 5 and Section 6 respectively. We conclude the paper and point future directions in Section 7.

2. Related work

Early work on robots as social partners for children can be found in studies conducted by Kanda et al. [10]. A robot was introduced in a school to interact with children during their recess time. Children were free to interact with the robot as long as they wished. Contrary to our work, the robot was provided with several non-goal directed interactive behaviors which could allow for series of brief interactions.

In a similar setting, Tanaka et al. immersed the QRIO robot in a classroom of toddlers (18- to 24-month old) during 5 months in three phases [11]. In the first and third phases the robot behaved using a full repertoire of random behaviors. In the second phase the robot performed a dancing activity. While high levels of interaction were found during phases 1 and 3, it significantly dropped during phase 2. The results on the dance study are reported in [4]. Two dance behaviors were evaluated: canned, the robot performed a pre-programmed movement while playing music; and interactive dance, the robot imitated the child's moves using its upper body only. Each condition was evaluated for three days. An additional one is introduced later on, where only music is played in the room, without the robot being present. Unlike our work, children were free to go and interact with the robot at any time during the day. Comparing the different conditions, children went to visit the robot more often in the interactive mode, suggesting that this condition was quite attractive.

Work on developing a social robot with empathetic capabilities (facial expressions only) to play chess with children is presented by Leite et al. [12]. In their work 5 children played over a five-week period. The results show that the social presence perceived by the children decreases through time, when the novelty effect diminishes. They suggest that the low repertoire of actions the robot is provided with could be one of the reasons for the attention decay.

A study on the impact of social interactions on effective learning is introduced by Okita and Ng-Thow-Hing [13]. In their work they compare three learning strategies (lecture, cooperative and self-directed) in a table setting task, where the robot behaves either in a monotone way or a more human-like style (voice and gestures only). Results show that the combination of cooperative learning strategy and human-like behavior achieves higher performance results, suggesting that the learning styles and social features had an impact, especially in young users (4–6 year-old).

A different approach for learning through the social interaction is proposed by Tanaka and Matsuzoe, where a care-receiving robot to promote children's learning is studied [14]. They propose a scenario where instead of having the robot as tutor/teacher, the child becomes a teacher for the robot. 17 participants between 3 and 6 years-old took part in the experiments. The results suggest that the teaching framework proposed helped children learn English verbs efficiently.

Our work is placed in between these works, where the target age is 7–12 years-old, there is a specific task to be carried out, and the robot is provided with both specific engaging behaviors related to the task and high movement capabilities.

Table 1
Summary of strategies observed during the dance sessions. The third column indicates whether they have been implemented in the current system.

No.	Strategy	Implemented
1	Abstract concept vs. specific motion learning	✓
2	Individual vs. collective training	✓
3	Non-verbal and verbal feedback	✓
4	User specific adaptation	✓
5	Incremental sequence learning	✓
6	Performance and appreciation	✓
7	Motivational feedback	✓
8	Learning resources	✗
9	Music	✓
10	Creativity support	✗
11	Problem identification and support	✓
12	Activity summary	✓

3. Analyzing human–human instruction sessions

The aim of having observation sessions is to study and to analyze human–human interaction within everyday activities that children take part in. While the global goal is to study interaction strategies used between a tutor and pupils, a more specific one within the dance context is to analyze dance methodologies and techniques to teach dance to children. Some of the questions we would like to answer are: How does the teacher prepare a session? How does she/he adapt the teaching methodology based on the group to be taught? How to motivate children? How to keep them engaged?

A researcher attended 30 dance sessions which spanned four months in different schools in London.[1] The target age participants were between 7 and 10 years-old divided in 5 groups. Each group was composed of around 20 students. Only journal notes were taken by the researcher through the sessions since video recording instruments were forbidden in schools due to privacy concerns.

3.1. Observations summary

A summary of the observations annotated during the dance sessions we took part in is shown in Table 1. Annotations were focused on the observation of two main aspects: instruction methods and engaging/motivational techniques. While the former covers any type of instructions used by the teachers to convey knowledge, the latter refers to any relevant behavior the teachers performed to draw children's attention towards the task. Moreover, discussions with the teachers regarding the methodologies used were also included.

[1] The dance sessions were organized by the Language Of Dance Centre.

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