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The NAO robot as a Persuasive Educational and Entertainment Robot (PEER)

– a case study on children's articulation, categorization and interaction with a social robot for learning

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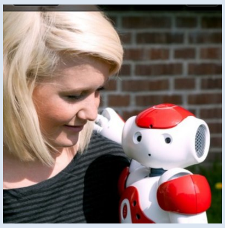

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Abstrakt

I denne artikel undersøger vi robotten NAO som en 'Persuasive Educational and Entertainment Robot (PEER)' og præsenterer resultater fra et casestudie med NAO i danske folkeskoler. Vi fokuserer på børns italesættelse, konceptuelle kategorisering og kropslige interaktion med NAO, og undersøger NAO's rolle som henholdsvis 'værktøj', 'social aktør' og 'simulerende medium' i læringsdesigns. Casestudiet peger på, at børn intuitivt kategoriserer NAO som social aktør, dog er kategoriseringen kontekstuel og dynamisk. Resultaterne indikerer også, at skift i kategorisering har potentiale til at skabe mulighed for kritisk refleksion. Teknologiers "tøven", forsinkelser og fejl kan således potentielt betragtes som muligheder for observation, refleksion og læring. Endeligt fandt vi, at børns aktive simulation gennem italesættelse, narrativer, imitation og indøvning af sociale koncepter kan give lærere og forskere et særlig indblik i børns motivation, og således ideer til at styrke børns deltagelse og engagement i NAO-støttede læringsaktiviteter.

ABSTRACT

In this paper, we examine the robot NAO as a Persuasive Educational and Entertainment Robot (PEER) and present findings from a case study on NAO in Danish primary schools. We focus on children's practice of articulation, conceptual categorization and embodied interaction with NAO, and investigate the role of NAO as a 'tool', 'social actor' or 'simulating medium' in learning designs. The case study suggests that children intuitively categorize NAO as a social actor. However, this categorization is contextual and dynamic. Furthermore, findings indicate that shifts in categorization have the potential to create moments for critical reflection. Thus, technologies' stalls, delays and mistakes could possibly be considered opportunities for observation, reflection and thus learning. Finally, we found children's active simulation through framing, narration, imitation and rehearsal of social concepts to be windows of opportunity for teachers and researchers to get insights into children's motivations, and thus ideas about how to facilitate children's participation and engagement in NAO-supported learning activities.

BACKGROUND

Robots are increasingly employed for educational purposes as either the subject or tool in specific curricula or as a means to improve student motivation in learning activities (Mubin et al., 2013). Particularly in science education, different hands-on programmable robotic kits are used to facilitate interest in and understanding of technology and programming; concretizing otherwise abstract, theoretical concepts (Benitti, 2012). Similarly, we see an increase in the application of anthropomorphized robots to facilitate motivation and support learning, not just in science teaching but also in primary and secondary school in general and special needs education, in particular (Scassellati, Admoni & Mataríc, 2012).

The humanoid robot NAO is an example of such anthropomorphized robots. Originally, it was developed as a research platform in the field of Human-Robot Interaction (HRI) in 2006, but now in its 5th generation it is widely used in both research and as a teaching aid in science, technology, engineering and math (STEM) (Aldebaran Robotics, 2015). According to its developer Aldebaran Robotics, more than 70 countries now use NAO in computer and science classes from primary school through to university (Aldebaran Robotics, 2015) and NAO is currently the most commonly used social robot in HRI-studies presented at international conferences such as International Conference on Human-Robot Interaction (HRI, 2015) and International Conference on Social Robotics (ICSR, 2015). NAO stands 58 cm tall and perceives the world through different sensors, including microphones, cameras and tactile and pressure sensors and it communicates through movement (25 degrees of freedom), colored LED lights, sounds and speech (19 different languages). It is programmable in both a drag-and-drop language (Choregraphe) and Python and C++ for experienced programmers.

In Denmark, schools are also starting to use NAO as an educational tool. Choregraphe's visual programming interface allows novices to program it, and thus Denmark was the first country to introduce NAO as a teaching aid as early as primary school (Teknologisk Institut, 2015). The focus on primary school children programming NAO is to our knowledge unique to Denmark. Currently, more than 90 NAO robots are implemented at all levels of the educational system - from day care to graduate school - for purposes as diverse as the inclusion of children with special needs in primary schools (Greve Kommune, 2015) and the talent development of high school students with specific interests in STEM (ScienceTalenter, 2015). In Denmark, NAO is even introduced in preschool (Sørensen, 2015).

INTRODUCTION

Various research fields, including HRI and Persuasive Design and Technology-Enhanced Learning explore the application of robots and robot technologies as motivational tools and companions in education. In HRI, a distinction is often made between what Han (2010) has termed *educational robotics* (hands-on robotic kits) and (social) *r-learning service robots*, respectively. Extensive research in educational robotics shows that hands-on robotic kits can be valuable educational tools that support a constructionist approach to learning, since they translate abstract theoretical concepts through physical interaction and bodily experience and allow for new forms of engagement and participation in learning activities (Papert, 1993, Caprani, 2010, Majgaard, 2010, Majgaard, Nielsen & Misfeldt, 2011 and Majgaard, 2012). From research on r-learning service robots we know that social, anthropomorphic/zoomorphic robots may appeal to students in a different way compared to the mechanical looking and machine-like robots. These robots seem to be socially engaging and facilitate motivation for social interaction, which is viewed as both a prerequisite (for participation) and a challenge, particularly for children with special needs (Kozima, Nakagawa, & Yasuda, 2005, Lee, Kim, Breazeal, & Picard, 2008, Dautenhahn et al., 2009, Robins, Dautenhahn, & Dickerson, 2009, Scassellati, Admoni & Mataríc, 2012). Persuasive Design makes a similar distinction in the role of the technology, i.e. as a tool or social actor, and adds a third category; simulating medium, which refers to technologies that provide compelling experiences, not otherwise accessible, through simulation. These three categories each come with a set of persuasive principles, which guide the development, deployment and analysis of technologies, designed to motivate attitude or behavior change (Fogg, 2003).

In Han's distinction, the NAO robot is both an r-learning service robot and an educational robot. The design is human-like, but at the same time, it is somewhat mechanical looking. It is 'social' in the sense that it is interactive through speech, gestures, eye gaze etc. much like humans, but it is also programmable through the (perhaps not particularly intuitive) programming interface. Thus, in this paper we are particularly interested in investigating the roles and relations of the NAO robot in a specific educational setting, i.e. whether (or when) the children actually perceive NAO more as a 'tool' (similar to the hands-on robotic kits) or more as a 'companion' (r-learning service robot/social actor). We want to explore whether this categorization is static or dynamic (i.e., develops and changes over the course of the interaction) and how it is reflected in the children's articulation of NAO, and discuss how this could be related to and affected by their motivation to engage in the present learning activities.

The case study was conducted in the context of the research- and innovation project FremTek (FremTek, 2014) in which 20 school classes from 3rd grade to high school participated in user-driven teaching experiments extending from 8 to 20 hours. The overall aim of the project was to explore how NAO-robots and 3D-printers can support learning environments and to understand didactic design as a prerequisite for successful implementation and application of advanced technologies in teaching (Majgaard et al., 2014). In this paper, we focus specifically on the

NAO-robots from the theoretical Persuasive Educational and Entertainment Robotics (PEERs) perspective. We focus on articulation, conceptual categorization and embodied interaction as an analytical framework to gain insights into the relations between the children and the robot as well as their motivation and engagement in the interaction. The empirical data in the case study was collected at one particular school and consists of video and non-participant observations, in situ interviews and semi-structured focus group interviews with the students, interviews with the teachers as well as written evaluations.

In the following, we start by introducing the notion of Persuasive Educational and Entertainment Robotics (PEERs) as a theoretical concept combining theories within Persuasive Design, HRI and didactics and their respective research cross-fields. In the following section *"Language and categorization: an analytical framework"*, we look at different approaches to language and categorization related to social robotics as the analytical framework for the case study. We conclude this section with our research questions. A presentation of the case study design then follows in the section *"Case study and methodological approach"* including background, data collection methods and choice of data analysis examples. In the section, *"Empirical analysis and discussion"* we apply the theoretical and analytical framework to the data examples and discuss possible implications in relation to our research questions. Finally, we conclude with limitations and possible directions for future research.

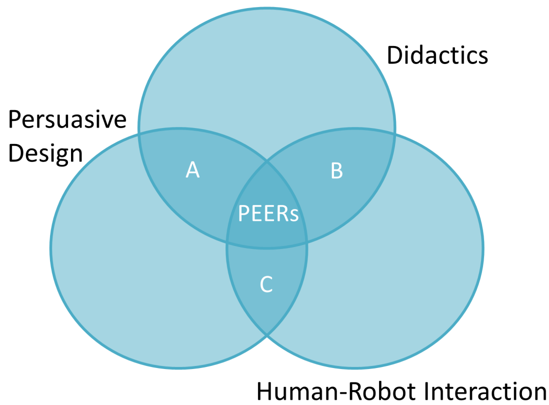
PEERS: A THEORETICAL PERSPECTIVE

The notion of Persuasive Educational and Entertainment Robotics (PEERs) introduced in (Bertel, 2012) is a three dimensional concept combining theories of motivation, interaction and learning within the fields of Persuasive Design, Human-Robot Interaction and didactics. These research fields and their respective intersections (see figure 1) covers a wide range of research on the application and impact of robots and robot technologies in teaching. In addition to this, the PEERs framework provides an overview of related research and technologies, from which the development of social robots for education can gain valuable insights, that is:

- *Persuasive Learning Designs* (which covers the application of ICT tools in education in general but with particular attention to the dialectic relationship between teaching and persuasion (i.e. persuasion as a core element of didactic designs and learning as a prerequisite for behavior change). The development of social robots for learning can thus gain valuable insights from different related but very diverse fields, e.g. educational psychology, play-based learning, serious games and game-based learning as well as research on contextual factors of didactic designs affecting motivational structures and value sensitive design methods in education (Gram-Hansen, 2012, Majgaard, 2012, Helms & Rahbek, 2012, Hansen, 2012, Misfeldt, 2014, Gram-Hansen & Ryberg, 2015)

- *Persuasive Robotics* (in HRI also referred to as Socially Assistive Robotics). This field covers the application of social robots that motivate behavior change through social support (as opposed to physical manipulation), e.g. in rehabilitation, cognitive/physical therapy and healthcare. (Feil-Seifer & Mataric, 2005, Short et al., 2014)
- *Educational Robotics* (hands-on robotic kits such as LEGO Mindstorm applied mostly in STEM education). The emergence of simple, programmable robotic technologies played an important part in the initiation of constructionism as an educational research field (Papert, 1993) and their adaptability and rebuildability is said to facilitate learning and collaboration through processes of active experimentation, observation and reflection (Papert, 1993, Caprani, 2010, Majgaard, Misfeldt & Nielsen, 2011)

We argue that the PEERs framework creates the opportunity to compare these related research fields theoretically and compile their respective design strategies and principles of application when developing social robots specifically with the purpose of facilitating motivation and learning (Bertel, 2012).



Figur 1. Persuasive Educational and Entertainment Robotics (PEERs) names the intersection between Persuasive Design, Human-Robot Interaction and didactics. Related fields are; A. Persuasive Learning Designs; B. Educational Robotics; and C. Persuasive Robotics/Socially Assistive Robotics. (Bertel, 2012).

From a Persuasive Design perspective, motivational aspects of technologies can be categorized as persuasive principles related to the technology as either a *tool*, *social actor* or *simulating medium* (Fogg, 2003). Naturally, principles from all three categories are at play in most motivating learning experiences. Thus, these categories are contextual and perhaps not particularly distinct. However, they do inform about the role of the technology and emphasize the learners' experience and conceptual understanding of the technology in the interaction. The addition of design principles and theories from Persuasive Robotics and Persuasive Learning Design can contribute to this trichotomy by further defining how a robot could be understood as a ”tool", "social actor" or "simulating medium" within the specific context of education, thus, making it more applicable to the design of social robots for learning.

SOCIAL ROBOTS AS SOCIAL ACTORS – CARE AND COMPANIONSHIP

Although the particular meaning of 'social' is a complete research area in itself, from a Persuasive Design perspective, robots designed to resemble humans, animals or other 'social entities' are inarguably social actors of some sort. Anthropomorphized robots engage in social interaction much like humans through conversation, eye contact, body language etc. However, Persuasive Design has a relatively narrow view on motivation in relation to persuasive social actors, focusing primarily on the persuasive principles of visual attractiveness, similarity, reprocity, praise and authority (Fogg, 2003). Thus, we argue that research in Socially Assistive Robotics as well as technology-enhanced learning can help to broaden this perspective (Bertel & Rasmussen, 2013). For instance, in Persuasive Design it is argued that technologies as social actors can be particularly persuasive in the role of authorities in the interaction. However, research in Socially Assistive Robotics questions the persuasiveness of robots in the role of an authority, e.g. reporting how dominant behavior in robots, particularly with goals incongruent to the user's, have been found to cause psychological reactance (Roubroeks, Ham & Midden, 2010). Similarly, the social constructivist approach to learning often explicit in technology-enhanced learning emphasizes the educational context as one of asymmetry (Deci et al., 1991). Thus, the potential of educational technologies, and PEERs in particular, could be to reduce this asymmetry. For instance, in previous work we have suggested more equal or reverse roles of authority (e.g. the robot as a peer tutor or the user as caregiver/instructor) as a way to increase motivation in particular contexts of asymmetry, such as special needs education (Bertel & Rasmussen, 2013 and Bertel & Majgaard, 2014).

SOCIAL ROBOTS AS TOOLS – AN OBJECT TO THINK WITH

Similar to the notion of technology as social actors, Persuasive Design also proposes a relatively narrow take on technologies as persuasive tools, focusing mostly on design principles that relate to system design; *reduction, tunneling, tailoring, suggestion, self-monitoring, surveillance, and* *conditioning* (Fogg, 2003). However, by combining Persuasive Design with technology-enhanced learning in general and educational robotics in particular, we can get some ideas about how social robots can support a constructionist approach to learning. The constructionist approach to learning as developed by Papert (1993) builds on the combination of a cognitivist approach to knowledge creation and interactive technology for learning. Papert emphasizes the interaction with physical objects as a means to construct new knowledge, and thus argues that interactive technologies can become "objects to think with" (Papert, 1993). This have been demonstrated within educational robotics, and research shows that the hands-on robotic kits translate abstract theoretical concepts through physical interaction and bodily experience and allow for news forms of engagement and participation in learning activities (Papert, 1993, Caprani, 2010, Majgaard, 2010, Majgaard, Nielsen & Misfeldt, 2011 and Majgaard, 2012).

SOCIAL ROBOTS AS SIMULATION – A MEDIUM FOR IMAGINATION

The idea of social robots as medium for simulation could prove itself useful in HRI. In the debate on social robots as companions, however, some HRI scholars use the term on the background of a metaphysical claim. Thus, simulation comes to mean the opposite of reality, that is, it is not real but merely an appearance (i.e. the robot appears to have capacities that it in fact does not have). With the understanding of simulation as the opposite of reality, the term comes to have a negative connotation, which is reflected in the work of e.g. social psychologist Sherry Turkle (2010), in which scenarios are discussed involving robots simulating human capacities and children not seeing the difference, allowing a false and even degrading relationship to develop. This use of simulation naturally raises ethical concerns. However, the connection to Persuasive Design in PEERs provides a useful theoretical context not necessarily related to the metaphysical debate. First, build into the notion of Persuasive Design and particularly Persuasive Learning Design lies an ethical demand emphasizing that one cannot base persuasion upon coercion or deception (Fogg, 2003 and Gram-Hansen & Gram-Hansen, 2013). Secondly, persuasive design provides an alternative understanding of the concept of simulation as conscious imitation (i.e. the technology supports the user's rehearsal of future or otherwise inaccessible events). The focus on the users' active participation and co-creation in the experience provides the opportunity to understand simulation on the background of *imagination*. That is, children use simulation as part of play to understand how things could be under different circumstances and therefore this tells us something about contextualization. Here the idea is not that two different worlds (one real and one fake) are created but simply that we make up possible scenarios from where we can play around with the different components. This perspective on simulation could be helpful for the understanding of how children find NAO motivating. Thus, we can replace the question of whether the children are "fooled" by NAO to that of what possible roles and relations the children imagine having with NAO in different contexts, and how this affects their motivation to engage in NAO-supported learning activities.

LANGUAGE AND CATEGORIZATION: AN ANALYTICAL FRAMEWORK

When it comes to the analysis of social robots in education, we argue that children's articulation and categorization provide valuable insights into the specific context and possible roles of robots as tools, simulation media and companions in practice.

The study of language and the relationship between language and categorization have engaged many scholars from many different areas of research including philosophy, cognitive science, psychology, linguistics, anthropology, AI research etc. As Jan Nuyts (2001) writes it is not a controversial claim that language is always to be examined in relation to human categorization because language is undeniably an aspect of human mental activity. What is, however, causing conflict, is the question of whether categorization precedes language, or vice versa. Roughly, one could understand this discussion from two oppositional sites; those who are in favor of the priority of categorization over language, since language is merely a means for expressing our categories; and those who are in favor of the priority of language over categorization, arguing that language is in fact shaping and even determining human categorization (Carruthers & Boucher, 1998). As an attempt to make the discussion more nuanced, some scholars have suggested that the relationship between language and categorization is to be understood in terms of mutual constitution rather than in terms of priority (Davies, 2003).

Within the humanities, the debate on the relationship between language and categorization has generally remained theoretical. Thus, the analysis of this relationship rarely includes concrete empirical research. However, this debate might in fact be very relevant in the study of social robots in settings such as schools, eldercare and hospitals. We present a few examples as to why in the following.

Sherry Turkle, whom we mentioned earlier, has for many decades researched how children relate to and categorize different kinds of technologies and in her current research, she includes social robots. In *Alone together* (2010) she presents her analysis and concerns about the way children categorize social robots based on the many interviews she have conducted from both field research and clinical studies. Turkle observed that children began to categorize and think about social robots in terms of care, friendship and companionship - concepts normally reserved for living beings. Therefore, Turkle argues, after their encounter with social robots children no longer speak about their relationship with them based on conceptual knowledge but instead on what these social robots seems to be capable of. Thus, the way children speak about social robots seem to indicate that they challenge how we normally distinguish between technological and living entities.

Psychologist Peter Kahn and colleagues (Kahn et al., 2011) too investigate how children relate to and categorize social robots. They found that children are unwilling to commit to categories as *living* or *non-living* entity and speak of social robots as neither or as "in between" (Kahn et al., 2011). These results suggest that even though we do in fact have ways of distinguishing living and non-living entities linguistically, it seems children find their categorization of social robots in conflict or unfitting with this established category. Kahn thus advocates the introduction of a completely new ontological category specially for robots, which they try to capture in the notion of "robotic others" (Kahn et al. 2004, 2011).

So far, the examples have shown that our conceptualization of social robots is somehow no longer based on a classical category formation or is not already incorporated in our language. It is, however, also important to show how language itself shapes categorization. Philosopher Mark Coeckelbergh has, from a phenomenological approach, analyzed how children and adults categorize their relation with social robots and argues that it would be beneficial to understand this categorization by focusing on the constructive role of language (Coeckelbergh, 2010, 2011).

According to Coeckelbergh researchers should keep in mind that language is not only a medium for humans to represent their reality but that language also takes part in constructing it. To test this hypothesis in relation to HRI, researchers at the MIT Media Lab decided to set up an experiment in which the linguistic environment was manipulated (Kory & Kleinberger, 2014). They did so by asking whether the introductory presentation or framing of a robot by the experimenter/parent influenced children's behavior and affective responses toward the robot (Kory & Kleinberger, 2014). In the experiment, two different conditions were designed in which the experimenter would present a social robot as either mechanical (i.e. referred to in terms of "it") or as living/social (i.e. addressed in terms of "you"). According to Kory and Kleinberger, the experiment does confirm the hypothesis that the linguistic framing of social robots affects the way we come to relate to them.

RESEARCH QUESTION

Based on the above theoretical reflections on Persuasive Educational and Entertainment Robotics (PEERs) and our approach to language and categorization in relation to social robots, we can state the following research question:

How do children articulate and categorize the NAO robot (as a tool or companion) and how does this relate to their motivation to engage in NAO-supported learning activities?

- Do children articulate, frame and perceive NAO more as a tool, or rather as a companion, and is this categorization static or does it change over the course of the interaction?
- To what extent do children use NAO as a medium for simulation (i.e. imagination, imitation and rehearsal of social concepts) and does this relate to and affect their motivation to engage in the NAO-supported learning activities?

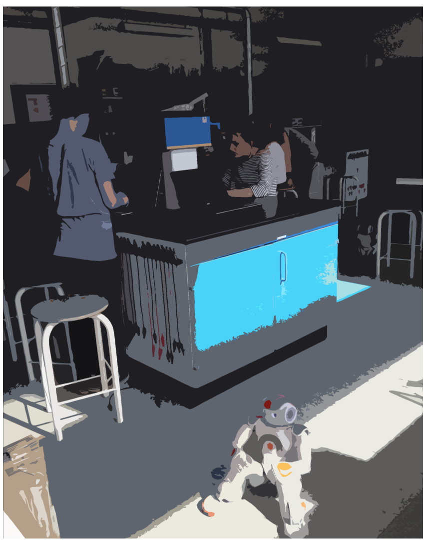
CASE STUDY DESIGN AND METHODOLOGICAL APPROACH

As mentioned earlier, we conducted the case study as part of the research project FremTek (FremTek, 2014), which was based on a design-based research approach, emphasizing experiments and critical reflection as the core of the research method with interventions taking place in the natural surroundings allowing learning from practice (Majgaard et al., 2014).

Each class had access to a set of three NAO robots and eight PCs with Choregraphe. The teachers agreed to use NAO in their lessons for 5-6 weeks, at a minimum of 8-10 hours in total. The design-based research setup was structured as follows:

- Initially, the teachers participated in a two-day workshop with one day focusing on hands-on experience with NAO and the Choregraphe programming interface; and one day focusing on the teachers' preparations and development of didactic plans with articulated learning goals.
- Teaching experiments in practice (8-20 lessons). We visited the schools and conducted interviews and observations.
- The teachers collected the children's productions (e.g. Choregraphe programmes) and filled in a retrospective evaluative questionnaire.

The empirical data for this case study on the NAO-robots potential as Persuasive Educational and Entertainment Robots (PEERs) was collected during three visits over a 3-week period among 7th grade school children (aged 13-14) at a public school in the Horsens area. Data consisted of in



total 6 hours of video recordings with three different cameras, non-participant observations complimented with field notes, in situ interviews and 4 semi-structured focus group interviews with in total 16 children as well as a written teacher evaluation. The teaching lessons took place in the schools physics room. The first two days of fieldwork were structured with an introduction to NAO by one of the teachers (and one time two "super-user" students, who had also attended the programming workshop). Afterwards the children worked with NAO in smaller groups (2-3 children each). The introduction took place in the lecture area, whereas the practical part of the teaching experiment took place in a more open, group-based workspace (see photos). We video-recorded the introduction from three

angles. Later we reorganized the cameras to capture as much of the group collaboration (screen-work, physical manipulation of NAO etc.) as possible. This proved to be somewhat a challenge, since the children had to share the robots and thus moved around quite a lot. We observed and documented the actions and reactions of the robot and the children. During the non-participant observations, we also conducted some short in-situ interviews. While the children were working with NAO, we asked some of them to participate in a focus group interview, which took place at another location at the school. All focus groups consisted of two girls and two boys. None of them had prior experience with NAO. Some of the questions guiding the interviews were:

> *Are you generally interested in technology?*
> *What did you think the first time you saw NAO?*
> *Is there a difference between your expectations of NAO capabilities and its actual capacities?*
> *If you should describe NAO in three words, what are they?*
> *What is the best and worse about NAO?*
> *Does it matter that NAO looks like a little human?*
> *Do you experience NAO as something more than an instrumental technology?*
> *What roles do you think a humanoid robot like NAO could have in our society?*
> *Would you be interested in working with NAO again or in a different setting?*

The interviews were recorded and transcribed for analysis. The video data was organized and reviewed and situations and interactions relevant to the specific research questions were selected for transcription.

EMPIRICAL ANALYSIS

For further findings and details across all case studies in FremTek, e.g. with attention to the teachers development, practical application and evaluation of NAO-supported didactic designs, we refer to Majgaard et al. (2014). This particular analysis' point of departure is a techno-philosophical analysis of the data presented in a previous paper by Hannibal (2014) which revealed contextual differences in terms of how the children applied gender pronouns to NAO:

> During the time when the schoolchildren were programming and interacting with the humanoid robot NAO, they did not hesitate to refer to the robot as 'han'/'he', 'hun'/'she' or 'den'/'it'. However, during the time when some of the schoolchildren were interviewed about how they experienced working with NAO they consistently referred to NAO as merely 'den'/'it'.
>
> (Hannibal, 2014: 345)

In both the English and Danish language the use of 'it' normally refers to all inanimate entities as they do not exhibit any physical gender which most living beings have. According to Hannibal, the change in articulation could indicate that the children's categorization is dynamic, i.e. context dependent. In the paper, she focuses on dual process theory of human cognition, stating that the individual can utilize two different kinds of reasoning (one unconscious and associative, the other conscious and rule-based) to understand how context and categorization might be related in the case of robots for learning. However, the idea of dynamic categorization could also be interesting from a motivational and relational point of view. From a PEERs perspective, it is interesting to ask if the articulation and categorization shifts in specific situations related to the role of NAO as either tool, social actor or simulation and if this translates into specific motivational states, that the children experience.

APPLYING PEERS – AN ANALYTICAL EXAMPLE

To elaborate on this, we will look at an example (camera 3, 7th of April at 8:59). This data sample illustrates examples of NAO as both a tool, social actor and simulating medium, which also illustrates a shift in categorization. Thus, this data sample will be the starting point of the remainder of the analysis combined with related examples from the interviews and interactions as well as general observations from the case study.

In this example, two girls are programming NAO to stand up and wave. They are generally talking about NAO as a social entity using phrases (our translation) such as *"catch him", "oh that's so cute"* and *"just like a little baby"*. In the situation, they are sharing the NAO with another group of girls and waiting to connect to upload their NAO-behavior from Choregraphe to the physical NAO. Until now the two girls have been referring to NAO as he/him: *"Can we take him now?"*, *"Are we connected to him?"*, *"Should he stand or should we lay him down?"* etc. After uploading, they both sit on the floor waiting for 'him' to perform the behavior:

> One of the girls smiles and says, *"Come here"*, reaching towards NAO's hands much as one would while supporting a baby or small child getting on his feet. The other girl says *"come on little baby"* with a soft voice continuing: *"I am right next to you".* Both girls stretches their arms to support NAO while it is getting up and when it is almost standing, the girl behind NAO says *"good work"* and applauds. The girl in front of NAO waves with two fingers in what one could perceive as its visual field, expressing a calling phrase *"tutte li tut",* possibly to get NAO's attention. Since NAO is unable to finish the whole behavior and seems to freeze before waiving, the girl looks up at the computer with the Choregraphe interface and then towards the teacher (outside of the camera angle) and says, *"He's not waiving?"*. The teacher replies, *"Otto has some balance issues"* to which she responds, *"Its Anton",* rejecting balance issues as the explanation. She then wonders: *"It doesn't wave?"* and opens her hands as if to frame her statement as an inquiry. She then turns to the computer and the other girl requests: *"Try and start it again"*. In the following correspondences with the teacher and the other children she consistently refers to NAO as "it", e.g. *"But it's not waiving!"* (as a response to another child asking, *"Was that it?"*), *"It won't wave"* etc. She then reflects, *"Is waiving doing like this?!"* and imitates the movements of NAO, with a skeptical facial expression. Trying again with the help from one of the expert users, NAO still fails at waiving, though expressing other phrases such as *"hi"* and *"ouch".* She then switches to addressing NAO directly *"You are bad at waving"*, *"You are really sweet little friend but you cannot wave"*. While waiting for the other girl to fix the programming problem she looks at NAO and says, *"You have to wave sweet friend"* stroking very lightly NAO's hand.

> (4.40-7.19 minutes into video recording, camera 3 the 7th of April at 8:59).

NAO AS A PERSUASIVE SOCIAL ACTOR – COMPANION AND CARE RECEIVER

The proxemics and embodied interaction (including eye contact) between the girls and NAO as well as their articulation, tone of voice etc. are all indications that the two girls frame and experience NAO as something more than a mere tool for programming. The combination of the humanoid design and the (simulated) autonomy in the execution of behaviors seem to facilitate interactions similar to that of human-human encounters. However, it is interesting to notice the switch in pronoun to "it" when it does not meet their expectations. Certainly, one would not expect a similar reaction had it been a real baby failing to wave.

Another interesting aspect of this example is the actual framing of NAO as an infant. It would be tempting to label this observation gender-specific, i.e. a "motherly instinct" triggered by NAO's infant-like size, clumsy movements and the framing of the robot by the teacher and the expert users as a child e.g., *"You need to support him"*. However, other data examples contrast this. At least, some of the boys exhibited the same, perhaps 'parental', instinct for protection when interacting with NAO. The following is an example of such observation:

> One boy and a girl are trying out their programmed behavior on NAO. The boy is placing himself behind NAO in order to provide support in case NAO loses its balance. When NAO starts executing its chai-chi dance the boy says *"come on NAO, you can do it"*. Later, when testing the dancing behavior once more, the boy says *"come on my little chai-chi friend"* and while bending over NAO, holding two fingers in front of its vision, he adds with a commanding tone of voice *"look at the two fingers while you are dancing chai-chi"*.
>
> (1.21-1.25 and 10.21-11.21, camera 2, 7th of April)

Although we did not compare NAO in the role as an authority, companion or care receiver, in these examples and more it seemed like the children intuitively took on the role as the companion or caregiver in the interaction, which is consistent with prior work (Kanda et al., 2004, Bertel & Rasmussen, 2013 and Bertel & Majgaard, 2014).

During the three lessons, we observed many both linguistic and bodily expressions indicating that the children experienced NAO as something of a social entity rather than merely a technical tool for teaching programming.

Often they would seek eye contact with NAO when trying out their designed behaviors. They did ascribe human characteristics to NAO such as feeling sad or having free will. In several instances, we observed the children making faces at NAO (it even seemed they found it difficult not to) whenever the robot did something unexpected or in moments of delay (when waiting for the computer to connect or upload the behavior to the physical robot). For instance, in the following example, where two boys are programming NAO:

> The boys are mostly looking at the screen and working with Choregraphe, but when they switch from designing the behavior on the screen to testing it with the physical NAO, one of the boys turns towards NAO and sits on the floor. He waits for NAO to perform the action but it seems the delay is longer than he expected. He bends his head over NAO and addresses it directly, saying *"come on"* impatiently and pretends to be startled once it starts moving
>
> (5.46 minutes into video recording, camera 1, 7th of April at 13:42)

In this example, it seems the delay or upload stall creates a brief moment of "awkward silence" between the boy and NAO to which he reacts in a social manner. In other cases, these delays, stalls or even mistakes create room for reflection, which we will discuss in the following.

NAO AS A PERSUASIVE TOOL – A "STALL FOR REFLECTION"

In the case study, we found several examples of the children's conceptions about NAO as a tool in the most obvious sense (solving specific tasks and problems), especially in the interviews, e.g.: *"it could be your little assistant. That is what I would have done. Then I would have made it do my homework"*. In the following, however, we will consider NAO as a tool for reflective practice, i.e. as an "object to think with". In the analytical example with the girls, the stall in the robot behavior is not just a delay in the interaction or learning process, rather it is facilitating the learning process. It reminds her, that she is actually interacting with a programmable technology (which forces her to look at the computer and reflect on their work to locate the mistake). The children are perfectly capable of reflecting on the technology in the focus group interviews, however, these reflections are more related to the nature and capabilities of the technology (as we will see in the next section) and not particularly related to their own experiments and learning process. Thus, we argue that stalls, delays and mistakes could be considered not just as risks or obstacles to avoid (as otherwise argued in r-learning service robotics) but as possible opportunities for observation, critical reflection and (re)experimentation and thus (constructionist) learning. In this example, the girl learns several things. First, she acquires knowledge about the technology through reflection on the interaction flow with NAO as depending on correct programming (other examples from the case include insights into the sensitivity of the sensors, the accuracy of the speech-recognition system etc.). Secondly, she reflects on the concept of waving as a social construct, i.e. what constitutes a wave (perhaps not consciously yet, but in other case examples these social constructs are reflected much more explicitly, particularly when designing "appropriate" robot behavior, and in this sense NAO becomes a platform for *rehearsing social concepts*). Finally, she learns about programming issues (and later on NAO does actually wave). These moments for reflection are critical, since they rely on motivation and thus 'frustration'. Too little frustration, and the learner is bored; too much frustration and the learner resigns. Such example was also found in the case study, where a group of boys seems to "give up" (due to task complexity, not technical issues), relying completely on the help of the expert users and the teacher. Just the right amount of frustration, however, seemed to facilitate motivation in the learning process, which is consistent with constructive learning and the concept of reflection in-and-on action (Schön, 1983).

NAO AS PERSUASIVE SIMULATION – CAN YOU IMAGINE?

In this final part of the analysis, we will discuss NAO as a medium for simulation. Not as a question of whether NAO is able to "fool" the children (it is not) into thinking that it is autonomous or somewhat "alive", but in the sense that NAO facilitates imagination and reflection on the possible roles and relationships that robots and humans could have.

Some of the children explicitly imagined having a relationship with NAO as they would frame their interaction within a context of family play: *"this is our little baby"* or imagine possible future scenarios with it: *"I could become good friends with this one [NAO]*". One boy even pointed out to a classmate that NAO was merely a robot (implying that the classmate ascribed feelings and mental states to the robot) as he reacted emotionally to NAO being pushed over. In addition, we also found examples of children ascribing moral status to the robot, e.g. in the form of patience about NAO (*"You should really help him"* and *"You should comfort it").* In the example with the two girls, simulation was very explicit in their framing of NAO as that of an infant child. It could be argued, that there is a reciprocal exchange of simulation in this interaction. The girl herself simulates (imagines) a situation in which NAO is an infant, and NAO's simulation of behavior fits within this narrative. Even when the simulation fails, this is (consciously) framed within this narrative (*"you are really sweet little friend but you* *cannot wave"*) and at the same time she recognizes that these capabilities are just simulations by looking at the computer and the teacher, i.e. the "not waiving" is not considered "intentional". Additionally, simulation also manifested itself through *imitation*, e.g. in one example, the one girl suggested the other to mimic NAO's pose and in another example they both re-narrated NAO's failed wave and translated it into a salute.

DISCUSSION

In the case study, we found that the active simulation often took place right before or just after the testing of programmed behaviors, i.e. in the anticipation of what was to come. The children were perfectly capable of imagining and reflecting on future scenarios with robots in homes, schools, eldercare etc. in the group interviews. However, we argue that it is in this active simulation (conscious and unconscious framing, narration, imitation and rehearsal of social concepts) we as researchers; teachers and designers get insights into the children's motivations. For instance, in the case of the two girls framing NAO as a baby, the teacher could use this interest to design tasks such as defining, reflecting on and programming infant-like behavior and language onto NAO. This could support further academic discussion e.g. in relation to natural language processing in robots, machine learning and AI. In another case, where a group of boys were framing NAO within a football-narrative the teacher could work with analysis, design and programming of football player behavior – which is actually already a well-established scientific field in advanced robotics (Aldebaran, 2015).

CONCLUSION

In this paper, we have explored the social robot NAO as a Persuasive Educational and Entertainment Robot (PEER). Theoretically, through the combination of theories on motivation, interaction and learning within Persuasive Design, Human-Robot Interaction and technology-enhanced learning. Empirically, through a case study on the use of NAO robots in a Danish primary school. We analyzed the children's practice of articulation and embodied interactions with NAO with particular attention to the persuasive role of NAO as either a tool, social actor or medium for simulation in the interaction. We found that the children intuitively categorized NAO as a social actor. However, this categorization was contextual and dynamic. We found that shifts in the categorization as social actor or tool, e.g. related to the robot failing to meet the children's social expectations in specific situations (e.g. stalling, delaying, freezing or falling) could initiate social repairs (shifting categorization back to that of a social actor) or create moments for reflection, i.e. making NAO an "object to think with". Thus, we argue that stalls, delays and mistakes should not be considered only as obstacles to avoid (as argued in r-learning service robotics) but as opportunities for observation, critical reflection and thus learning. Finally, we found that active simulation (conscious and unconscious framing, narration, imitation and rehearsal of social concepts) are windows of opportunities for researchers, teachers and designers to get insights into children's motivations, and thus ideas about how to facilitate children's engagement in NAO-supported learning activities.

As a case study these findings naturally have certain limitations. As of now, we do not know whether these findings are applicable and replicable in different educational context, with different users or different social robots. Thus, we aim to explore these findings and the applicability of PEERs in general in learning environments more systematically through larger-scale, long-term and cross-contextual case studies in both formal and informal learning environments.

REFERENCES

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. Computers & Education, 58(3), 978-988.

Bertel, L. B. (2013). Persuasive Educational and Entertainment Robotics (PEERs). In Bai, S., Larsen, J. A., Madsen, O. & Rehm, M (red). 1 st AAU Workshop on Human-Centered Robotics. Aalborg Universitetsforlag

Bertel, L. B., & Majgaard, G. (2014). Persuasive Educational & Entertainment Robotics (PEERs)-Aligning Asymmetric Interactions in Education. HRI'14 Workshop on Humans and Robots in Asymmetric Interactions.

Bertel, L. B., & Rasmussen, D. M. (2013). On Being a Peer: What Persuasive Technology for Teaching Can Gain from Social Robotics in Education. International Journal of Conceptual Structures and Smart Applications (IJCSSA), 1(2), 58-68.

Caprani, O., & Thestrup, K. (2010). Det eksperimenterende fællesskab-Børn og voksnes leg med medier og teknologi. Tidsskriftet Læring og Medier (LOM), 3(5).

Carruthers, P., & Boucher, J. (1998). Language and Thought Interdisciplinary Themes. Cambridge University Press.

Coeckelbergh, M. (2010). You, robot: on the linguistic construction of artificial others. Ai & Society, 26(1), 61–69. Retrieved from http://link.springer.com/10.1007/s00146-010-0289-z

Coeckelbergh, M. (2011). Talking to Robots: On the Linguistic Construction of Personal Human-Robot Relations. In F. J. Verbeek & M. H. Lamers (Eds.), 3rd International Conference on Human-Robot Personal Relationships (pp. 126–129). Leiden, The Netherlands: Springer.

Dautenhahn, K., Nehaniv, C. L., Walters, M. L., Robins, B., Kose-Bagci, H., Mirza, N. A., & Blow, M. (2009). KASPAR–a minimally expressive humanoid robot for human–robot interaction research. Applied Bionics and Biomechanics, 6(3-4), 369-397.

Davies, M. (2003). Philosophy of Language. In N. Bunnin & E. P. Tsui-James (Eds.), Blackwell Companions to Philosophy (2nd ed.). Blackwell Publishing.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. Educational psychologist, 26(3-4), 325-346.

Feil-Seifer, D., & Matarić, M. J. (2005, June). Defining socially assistive robotics. In Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on (pp. 465-468). IEEE.

Gram-Hansen, S. B. (2012). Persuasive learning designs. Designs for Learning 2012, 153-154.

Gram-Hansen, S. B., & Gram-Hansen, L. B. (2013). On the role of Ethics in Persuasive Design. Ethicomp 2013.

Gram-Hansen, S. B., & Ryberg, T. (2015). Acttention–Influencing Communities of Practice with Persuasive Learning Designs. In Persuasive Technology (pp. 184-195). Springer International Publishing.

Han, J. (2010). Robot-aided learning and r-learning services. INTECH Open Access Publisher.

Hannibal, G. (2014). 'Dynamic'Categorization and Rationalized Ascription: A Study on NAO. Sociable Robots and the Future of Social Relations: Proceedings of Robo-Philosophy 2014, 273, 343.

Hansen, J. J. (2012). Tema 2: At designe e-læring-didaktiske perspektiver på uddannelsesdesign og didaktiske design. Tidsskriftet Læring og Medier (LOM), 5(9).

Helms, N. H., & Rahbek, J. U. (2012). Spildesign i Serious Games–en didaktisk udfordring?. Læring og Medier (LOM), 5(9), 1-18.

Kahn, P. H., Freier, N., Friedman, B., Severson, R., & Feldman, E. (2004). Social And Moral Relationships with Robotic Others.pdf. In 13th IEEE International Worksjop on Robot and HUman Interactive Communication (pp. 545 – 550). Kurasjiki, Japan: IEEE.

Kahn, P., Reichert, A. L., Gary, H. E., Kanda, T., Ishiguro, H., Shen, S., … Gill, B. (2011). The new ontological category hypothesis in human-robot interaction. In 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI), (pp. 159–160). Lausanne, Switzerland: IEEE. Retrieved from http://dl.acm.org/citation.cfm?id=1957710

Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. Human-computer interaction, 19(1), 61-84.

Kory, J., & Kleinberger, R. (2014). Social agent or machine? An exploration of how the framing of a robot affects prosodic mimicry and expressivity. In 9th ACM/IEEE International Conference on Human-Robot

Interaction, 2nd Workshop on Applications for Emotional Robots (pp. 1–5). Bielefeld, Germany.

Kozima, H., Nakagawa, C., & Yasuda, Y. (2005). Interactive robots for communication-care: A case-study in autism therapy. In Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on (pp. 341-346). IEEE.

Lee, C. H. J., Kim, K., Breazeal, C., & Picard, R. (2008). Shybot: friend-stranger interaction for children living with autism. In CHI'08 Extended Abstracts on Human Factors in Computing Systems (pp. 3375-3380). ACM.

Majgaard, G. (2010). Læreprocesser og robotsystemer: design af læreprocesser med robotter som medier og børn som med-designere (Doctoral dissertation, Syddansk Universitet).

Majgaard, G., Hansen, J. J., Bertel, L., & Pagh, A. (2014). Fra digitalt design til fysisk udtryk–anvendelse af 3-d-printere og NAO-robotter i folkeskolen. MONA-Matematik-og Naturfagsdidaktik, (4).

Majgaard, G., Misfeldt, M. & Nielsen, J. (2010). Robot Technology and numbers in the classroom. Cognition and Exploratory Learning CELDA, International Association for Development, AIDIS

Majgaard, G., Misfeldt, M., Nielsen, J. (2011). How Design-based Research, Action Research and Interaction Design Contributes to the Development of Designs for Learning. Designs for Learning

Majgaard, G. (2012). Tema 1: Design af computerspil i undervisningen: Fra indfødt spiller til reflekteret designer. Tidsskriftet Læring og Medier (LOM), 5(9).

Misfeldt, M. (2014, October). How Simulation and Game Simultaneously Frames Game Based Learning. In ECGBL2014-8th European Conference on Games Based Learning: ECGBL2014 (p. 389). Academic Conferences and Publishing International.

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. Journal of Technology in Education and Learning, 1, 209-0015.

Nuyts, J. (2001). Epistemic Modality, Language, and Conceptualization: a cognitive-pragmatic perspective. John Benjamins Publishing Company.

Papert, S. (1993). Mindstorms. Children, Computers, and Powerful Ideas. Basic Books.

Robins, B., Dautenhahn, K., & Dickerson, P. (2009). From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot. In Advances in Computer-Human Interactions, 2009. ACHI'09. Second International Conferences on (pp. 205-211). IEEE.

Scassellati, B., Admoni, H., & Mataric, M. (2012). Robots for use in autism research. Annual review of biomedical engineering, 14, 275-294.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action (Vol. 5126). Basic books.

Short, E., Swift-Spong, K., Greczek, J., Ramachandran, A., Litoiu, A., Grigore, E. C., ... & Scassellati, B. (2014, August). How to train your dragonbot: Socially assistive robots for teaching children about nutrition through play. In Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on (pp. 924-929). IEEE.

Sørensen, K. L. (2015, May). Robotter i dagtilbuddet. Rundt i Randers, 16, pp. 6

Turkle, S. (2010). Alone Together - Why We Expect More From Technology and Less From Each Other. New York: Basic Books.

Links

Aldebaran Robotics (n.d.). Who is NAO? [web page]. Retrieved from: https://www.aldebaran.com/en/humanoid-robot/nao-robot

Teknologisk Institut (n.d.). Nu får NAO fast plads i klasselokalet. [web page]. Retrieved from: http://www.teknologisk.dk/ydelser/nu-faar-nao-fast-plads-i-klasselokalet/33151

Greve Kommune (2015, March 25.). Greve vinder digitaliseringspris med robot. [news article]. Retrieved from: http://www.greve.dk/Om%20kommunen/Nyheder/2015/3/Digitaliseringspris%202015.aspx

ScienceTalenter (n.d.). NAO-ROBOT-CAMP. Drømmeteam fra H. C. Ørsted Gymnasiet vinder NAO-robot til ScienceTalenter [web page]. Retrieved from: http://www.sciencetalenter.dk/da/grundskole/camps-og-events/nao-robot-camp/