PEERs at Play: A Case Study on Persuasive Educational and Entertainment Robotics in Autism Education

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This paper introduces the notion of Persuasive Educational and Entertainment Robotics (PEERs) as the intersection between Persuasive Design, Human-Robot Interaction and Didactics and investigates the persuasive potential of PEERs in special needs education through an empirical study on the implementation and use of the robot seal PARO at a school for children with autism. Results include a categorization of user-developed concepts of PEER-supported interventions in special needs education as well as persuasive design principles that emerges from the comparison and combination of design strategies within Persuasive Technology, Human-Robot Interaction and Didactics.

**Keywords:** Persuasive Design, Human-Robot Interaction, Autism Education

Introduction

Robots are increasingly implemented as teaching aids and assistants at universities, secondary and even primary schools to increase interest STEM teaching (Mataríc, Koenig & Feil-Seifer, 2007 and Majgaard & Misfeldt, 2010) and language learning (Han & Dongho, 2009) by providing a platform for experimentation, reflection and collaboration. The application of robots to motivate social interaction and communication in autism education has also gained increased interest in recent years (Dautenhahn et al, 2009, Lee, Breazeal & Picard, 2008, Robins et al, 2009, Kozima, Nakagawaand Yasuda, 2005). For robots to succeed as motivational trainers, teachers and playmates their physical appearance, interactivity and social behaviour must match the users' needs and meet the demands of an ever changing educational context. This calls for well-established guidelines as to how such robots should be designed and in what ways interacting with them can support learning.

Within the field of Persuasive Design (PD) it is argued that technologies can be persuasive in the role as social actors. Naturally, from a PD perspective social robots can viewed as social actors since their main purpose is to engage in social interactions with humans and thus one might consider the principles of PD when designing social robots for persuasive purposes. From a Human-Robot Interaction (HRI) perspective, though, the design of robots for particular (often persuasive) purposes, has also received a great deal of attention in recent years. Thus, this paper shows that a lot can be gained from looking at the taxonomies of HRI when designing persuasive social actors. Furthermore, this paper argues that for robots to be persuasive within an educational context, one must also consider the conditions of this particular context of application. Specifically, this paper proposes the combination of PD, HRI and Didactics as a framework for designing robots that motivate play and learning. The notion of Persuasive Educational and Entertainment Robotics (PEERs) is introduced and based on a case study on the implementation of the therapeutic robot seal PARO at a school for children with autism, the different roles of the robot in persuasive interventions are outlined and discussed in relation to the framework. The paper is concluded with thoughts on the perspectives and limitations of the work with directions for future research.

Persuasive Educational and Entertainment Robotics (PEERs)

This paper builds on the work in (Bertel, 2012) which argues that the combination of theory on motivation, interaction and learning within PD, HRI and Didactics can provide a framework for designing robots specifically for the purpose of education. Thus, the PEERs model (see figure 1) is a conceptualization of robots designed to motivate play and learning as well as a categorization of related fields and technologies;
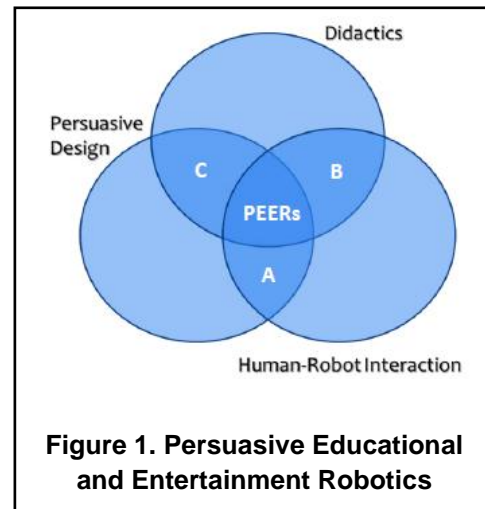
Figure 1. Persuasive Educational and Entertainment Robotics

A. Persuasive Robotics, i.e. robots that motivate behavior change through social support (e.g. robotic weight consultants that keep track of users' dietary information (Kidd & Breazeal, 2008) or service robots that elicits emotional responses to users' energy consumption (Vossen, Ham & Midden, 2010) to encourage a healthier or greener lifestyle).

B. Educational Robotics, i.e. hands-on robotic kits such as *LEGO Mindstorms* used to teach topics within STEM education. These robotic kits have generally been argued to support a constructionist approach to learning (Papert, 1980) and thus facilitate embodied learning through experimentation, reflection and collaboration (Mataríc, Koenig & Feil-Seifer, 2007 and Majgaard & Misfeldt, 2011)

C. Persuasive Learning Designs (PLD), also termed Persuasive Learning Objects and Technologies (EuroPLOT, 2010) covers the application of ICT tools to motivate and enhance learning. Theoretical concepts and design methodologies have been developed in (Gram-Hansen, 2012 and Gram-Hansen, Schärfe & Dinesen, 2012) with a particular focus on including the context of the interaction in the design of PLD's.

The conceptualization of PEERs creates the opportunity to compare these related research fields theoretically and compile their respective strategies and principles when designing social robots specifically with the purpose of motivating play and learning.

Robots in Persuasive Design and Persuasion in Robotics

The fields of HRI and PD have in common that they both argue robots as possible persuasive agents. From an industrial HRI perspective, robots are most often considered to be tools (with the primary purpose of increasing efficiency and reducing complex tasks and thus costs). However, from a PD perspective this is not viewed as particularly persuasive even though it quite possibly induces behavior (and perhaps even attitude) change. Within PD some technologies described as simulated objects could also be considered robotic (e.g. the well-known Baby Think It Over which provides compelling experiences to young women about the advantages and (particularly) disadvantages of early motherhood (Fogg, 2003). So according to the PD framework, a social robot that imitates the behavior of an animal or a human convincingly can also be viewed as a portable persuasive simulation technology provided that it seeks to highlight the impact of certain behaviors and motivate behavior or attitude change (Fogg, 2003). However, although it seems that whether a robot should be considered a tool (reducing complex tasks), a simulating medium (simulating physical, psychological or emotional intelligence) or a social actor (engaging in social interaction, providing feedback and creating social relations) would depend on the design of the technology, the task at hand and the context of the interaction, most of the principles that can be directly related to social robotics come under the persuasive role as a social actor. The

principles of this persuasive role are not limited to robots and include other technologies that possess social qualities as well (virtual avatars etc.). Here, it is argued that the fact that people respond socially to technologies has significant implications for persuasion as it allow these technologies to apply a host of persuasion dynamics that arises from social situations (Fogg, 2003). These social cues are then formulated into a set of PD principles (see table 1) that describes particular ways of utilizing these cues of social influence to motivate and persuade:

Table 1. Social Cues and Principles of Persuasive Social Actors

Cue	Examples	Persuasive Principle
Physical	Face, eyes, body, movement	Visually attractive PT is likely to be more persuasive
Psychological	Preferences, humour, personality, feelings, empathy	People are more readily persuaded by PT products that are somewhat similar to themselves in some way
Language	Interactive language use, spoken language, language recognition	By offering praise (words, images, symbols, sounds) PT can lead users to be more open to persuasion
Social Dynamics	Turn taking, cooperation, praise, answering questions, reciprocity	People will feel the need to reciprocate when PT has done a favour for them
Social role	Doctor, teammate, teacher, guide	The role of authority enhances powers of persuasion

Within robotics, the research field of social robots emerged from the area of biologically inspired robots and the idea that robots should be able to interact and share information, not with humans, but among each other, as is the case with swarm robots (Deneubourg, 2000 and Dautenhahn & Billard, 1999). From the beginning of this millennium, though, social HRI gained increased interest, and in 2003 the term *Socially Interactive Robotics* (SIR, i.e. robots whose sole purpose is to engage in social interaction) was defined (Fong & Dautenhahn, 2003) and a taxonomy of characteristics and key components of SIR developed (see table 2).

Table 2. Taxonomy of Socially Interactive Robots (SIR)

Properties	Example	Description
Morphology	anthropomorphic, zoomorphic, caricatured, functional	Establishes social expectations and provides information about the intended function of the robot
Emotions	anger, fear, sadness, joy, surprise, neutral and combinations	Facilitate credibility in HRI and serve as feedback to the user about the robots internal state
Dialogue	synthetic language, natural language, non-verbal cues	Exchange and interpretation of symbols and information about the context of the interaction
Personality	tool, pet, character, supernatural, human-like	A set of qualities which are particularly significant for a specific robot
Perception	face/gaze tracking, speech/gesture recognition, tone of voice	A social robot must possess a number of perceptual abilities to engage in social interaction
User Modelling	qualifications, experience, cognitive abilities	The ability to create different user models so as to adapt to and shape the interaction in relation to specific user characteristics
Situated learning	imitation, learning	The ability to transfer information, skills and tasks between robots and humans
Intentionality	targeted behaviour, theory of mind, joint attention	For people to be able to asses and predict behaviour, it is necessary that the robot expresses intentionality

Some of the characteristics in this traditional HRI taxonomy are similar to the social cues highlighted in PD. For instance the terms *morphology* and *emotions* cover qualities much like the physical and psychological cues of persuasive social actors. *Dialogue* can be viewed as a combination of the cues related to language and social dynamics. Finally, the robots *personality* is also similar to PD's idea about the social role of the technology. The remaining components revolve around particular cognitive abilities (perception, user modeling, situated learning and intentionality). One could say that the first four types of characteristics of HRI similar to PD focus on qualities that shape the social interaction, whereas the last four types characterize the prerequisites for fully autonomous social HRI.

The idea that robots can motivate behavior change through social support is not unknown to the field of HRI. This is also referred to as the overlap between SIR and Assistive Robotics, i.e. Socially Assistive Robotics (SAR), which most often describes assistive robotic technologies that support physical or cognitive rehabilitation not by physical manipulation but through social interaction (Feil-Seifer & Matarĭc, 2005). The SAR framework (see table 3) adds to the existing taxonomy for social robots the following concepts:

Table 3. Taxonomy of Socially Assistive Robots (SAR)

Properties	Example	Description
User population	elderly, users with physical or cognitive disorders, students	SAR can address various populations of users, ranging in age, impairment, and need.
Task	tutoring, physical therapy, daily life assistance, emotional expression	SAR must engage the user effectively, achieve the goals of the domain-specific activity and be responsive to the needs and requirements of direct users and indirect stakeholders
Interaction modality	Speech, Gestures, Direct Input	SAR interactions vary in type and modality. Interactions should be treated separately from the robot's personality and also describe the reciprocal interaction by the human user.
Role	Caregiver, therapy aid, companion	The role of the robot may be defined by the task it is assisting with, the user population it is working with and the impression it gives through its appearance and behaviour.

It can be argued, that these SAR concepts define Persuasive Robotics, i.e. the overlap between PD and HRI (see figure 1) which is distinguished from other types of social robots since having a predefined user group and task entails a specific (persuasive) intention. However, the SAR taxonomy has much greater focus on the target user and the context of the interaction.

Positioning PEERs: The Importance of Context in Persuasive Learning Designs
As argued in (Gram-Hansen, Schärfe & Dinesen, 2012) the traditional approach to PD as a context-independent framework limits its applicability as a design tool, particularly within the field of education. This holds for the principles related to the persuasive role as social actor as well. Here, the complex and highly contextual social cues that cause people to make inferences about social presence (i.e. physical, psychological, language, social dynamics and social roles) are reduced to a few narrow and unilateral principles revolving around only a fragment of those social cues (i.e. visual attractiveness, similarity and reciprocity, praise and authority). It could be argued that whether a social robot will be considered visually *attractive* depends on the user and the nature and purpose of the interaction. For instance, a human-like design was specifically avoided when designing a social robot to assist in the relocation of patients (Mukai et al, 2010). Its size, colors and visual design were chosen to signal cleanliness and robustness, but could also possibly be seen as intimidating in other contexts.

Similarly, as argued in (Bertel, 2010) the effects of *praise and rewards* are not constant over time or across contexts. Rather, they are mediated by the power structure in the social context of the interaction and the relationship between persuader and persuadee. Furthermore, although a technology can certainly be persuasive in the role as an authority, it is not difficult to imagine situations where authoritative behavior will have a detrimental effect on motivation, particularly within education. Thus, when it comes to the design of robots as social actors the PD principles do not really reflect the complexity or cultural and contextual dependency of the aforementioned social cues or provide a method for prioritizing and operationalizing them in specific designs. The taxonomic additions in SAR, however, contribute to both the PD and HRI frameworks as it stresses the importance of context in persuasive HRI and argues that particularly the role of the robot is defined by the task it is assisting with, the user population it is working with and the impression it gives through its appearance and behaviour (Feil-Seifer & Matarić, 2005).

PEERs at Play: A Case Study in Autism Education

To understand in what ways PEERs can facilitate motivation and what roles they can take on for specific educational purposes, we conducted a three month case study on the use of the social robot PARO at a school for children with autism.

Figure 2. The PEER PARO
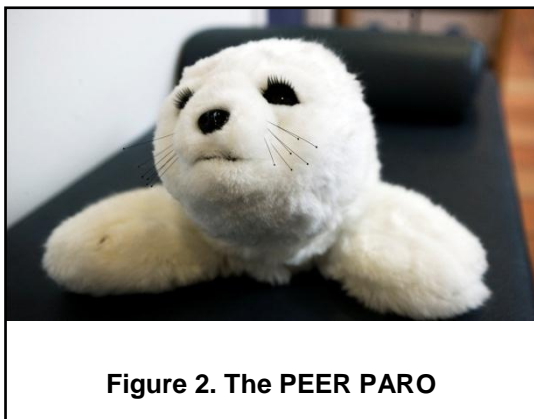
PARO is an autonomous robotic seal equipped with sensors and actuators and computational intelligence that enables it to simulate the sounds and movements of a real baby harp seal. It is being used with great success in dementia care in Japan and Europe as a robot companion with the purpose of increasing quality of life and reduce stress and anxiety and to provide a therapeutic tool for specific individual interventions (i.e. calming down, keeping/removing focus, reviving memories or language rejuvenating the identity as a caregiver etc. (Klein, Gaedt & Cook, 2013 and Wada & Shibata, 2007). Recent research suggests that PARO can be used as a facilitator of social communication for children with autism as well (Roberts & Shore, 2013).
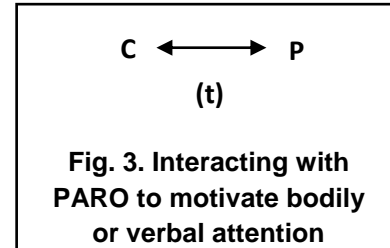
Whereas this related research was done in experimental settings, in this case we did a 3 month field study on the implementation and use of PARO at school for children with autism. This provided the opportunity to study long-term interactions in real-world educational settings as well as to promote a high level of user involvement in the development of the didactic designs supporting the use of PARO as a PEER. A total of three PAROs were implemented in 3 groups of children divided by age but with similar level of cognitive development (0-1 years of age) in which most have no spoken language and use alternative tools for communication. In total, 20 children and 7 teachers participated in study. The didactic applications of PARO were developed entirely by the participating teachers through 3 participatory design phases; exploration, co-ideation and co-creation/evaluation. The research setup and participatory framework is described in detail in (Bertel, Rasmussen & Christiansen, 2013). The following analysis will thus focus on the role of PARO as a PEER and the persuasive principles utilized in relation to this role, in particular.

The Role of PARO as a PEER in Persuasive Interventions

From the case study we found, that PARO had different roles in different teacher-developed didactic designs depending on the individual child, the goal of the intervention and the specific context of the interaction. The observed interventions were often centered on facilitating specific types of attention (bodily/verbal/social) and can be categorized as follows:
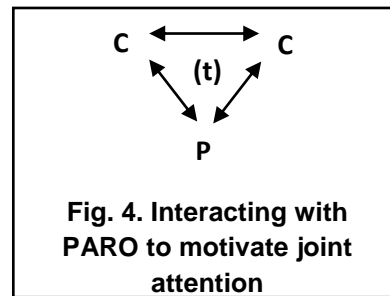
Bodily/Verbal Attention (see figure 3)

PARO was used as a sensory/cognitive stimulant to motivate verbalization and meaningful physical interaction (e.g. eye-contact, petting) either independently or supported by a teacher. This didactic design was deployed with a child, who would mostly touch things very lightly with his fingertips. With PARO he would engage in bodily interactions (using

Fig. 3. Interacting with PARO to motivate bodily or verbal attention

arms, chest and face) for longer periods of time. Also, the children were encouraged to verbalize their thoughts while interacting with PARO (e.g. "dog/ seal", "feed/sleep" and "tail/ eyes"). The teachers reported that the children were particularly interested in the eyes and would instantly seek eye-contact, which they would normally avoid. Here, it was thus the morphology, i.e. the visual, tactile and auditory feedback as well as the simulated perception (gaze-tracking, reaction to touch) that supported the persuasive intervention in question.
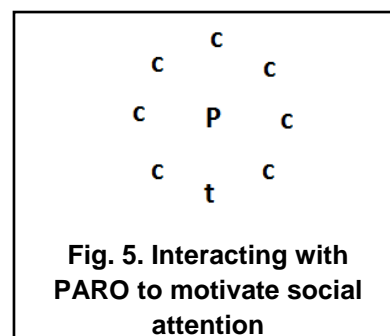
Joint Attention (see figure 4)

PARO was used as an object of joint attention between to facilitate social interaction. E.g., one group of teachers used the act of grooming PARO to get two children of whom one was afraid of the other to jointly touch PARO and eventually touch each other. They were already working on this particular goal. However, the children had never shaken hands or touched each other spontaneously until the sessions with PARO. In other cases, PARO was used with three children in

Fig. 4. Interacting with PARO to motivate joint attention

the introduction and rehearsal of social concepts such as care giving (e.g. grooming, feeding, and tucking in) and social events such as birthdays, dance parties and tobogganing. The teacher explained how the one child with more ability to get ideas for social concepts would instruct the second child who would then instruct the third child in the concepts he had learned from the first child. Here, PAROs morphology, personality and perceptive abilities motivated the children to take on the social role as teammates and sometimes even teachers.

*Center of Attention (see figure 5)*

PARO was used to create a centre of attention for a larger group of children. The context would often be a social gathering of some sort, e.g. singing Christmas Carols or playing musical instruments. The children would gather in a circle around a table or on the floor and PARO would be placed in the centre. The interaction would be initiated and maintained by the teacher and there would be less physical interaction between PARO and the children. In some cases PARO would even be turned off. However, it would be

Fig. 5. Interacting with PARO to motivate social attention

included in the social setting of the interaction, often initiated by the children. One teacher described how the children would provide PARO with a songbook of its own. Another teacher described how a child had changed the lyrics from a lullaby to be about PARO.

Directing and redirecting attention (see figure 6)
Finally, in some didactic designs, PARO was used to direct or redirect the attention of a child in certain difficult situations. For instance, if a child would have to stay focused on a specific task for longer than usual (e.g. for psychological evaluation), or if a child was intimidated either by external factors such as new and unfamiliar surroundings (e.g. going to a new playground or to church at Christmas) or by the fact

Fig. 6. Interacting with PARO to redirect attention

that he or she were to be the center of attention at a specific social event (e.g. visiting and introducing oneself at a new school). In these cases PARO would be used strategically to shift focus from the child's activities and performance to the activities and performances of PARO for which it would need the child's 'help'. Thus, rather than PARO accompanying the child, the child would accompany PARO as a helper, teammate or teacher.
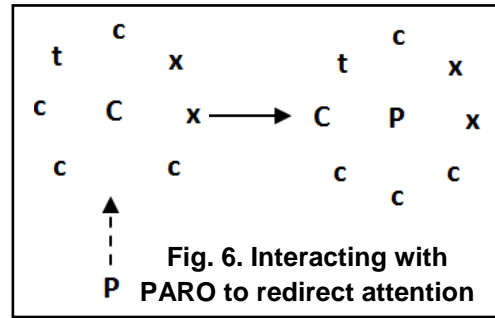
Conclusions and Directions for Future Work

Based on the empirical findings the role of the robot (as stressed in SAR) plays an important part in defining the persuasive potential of social robots for persuasive, educational purposes. In none of the above four types of teacher-developed didactic designs is there a particular preference for the robot in the role as an authority, and especially in the latter a directly inverse relationship between the user and the robot is considered the key to enhancing motivation. That is, in this case the user is the authority (the teacher, guide or helper) and the robot is the one requiring care and assistance. Thus, for the principles of PD (i.e. attractiveness, similarity, authority, praise and reciprocity) to be useful as PEER design tools, we argue that they must be extended and understood as the *strategic* use of particular properties of HRI in relation to a specific target group, task and context within education. The following is an attempt to do exactly this:

Table 4. Persuasive Principles of PEERs

Original Principle	Extended/Revised Principle	Related properties of HRI	Didactic Application
Attractiveness	Strategic design of physical cues	Morphology (SIR), Personality (SIR)	PEERs physical appearance should be attractive to both students and teachers
Similarity	Strategic design of psychological cues	Emotions (SIR), Intentionality (SIR), Perception (SIR)	PEERs should express intentions and affective states meaningfully. If possible be able to perceive these in users too
Praise and rewards	Strategic interaction design	Dialogue (SIR), Interaction Modalities (SAR), Social Dynamics (PD)	PEER interaction design must match the physical appearance and user preference. If possible it should be multimodal
Reciprocity	Strategic design of tasks	Task (SAR), Situated learning (SIR)	PEERs should solve tasks not solvable by humans. It should not replace humans.
Authority	Strategic design of social relations	Role (SAR), User Modelling (SIR)	PEERs should be able to assume different roles depending on user, task and context

In the future, these findings will be further explored in larger-scale, long-term and cross-contextual case studies with morphologically different social robots, for different users, tasks and contexts of interaction to investigate the applicability and replicability of these particular persuasive principles of PEERs.

Acknowledgements

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