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Bonding with Robotic Pets. Children's Cognitions, Emotions and Behaviors towards Pet-Robots. Applications in a Robot Assisted Quality of Life Intervention in a Pediatric Hospital

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Per a la Maria i l’Ada, és clar

Per a tots els nens i nenes valents als hospitals, la nostra inspiració

Cuando despertó, el dinosaurio todavía estaba allí

Augusto Monterroso, 1959

Abstract

This dissertation addresses the emergence of emotional involvement in the interaction with social robots. More specifically, we investigate the dynamics of children bonding with robotic pets to design robot based programs to improve patients' experience in pediatric hospitals. Pet-robots are robots that mimic real pets as dogs or cats, both in appearance and in behavior. We assume that gaining understanding of the emotional dimension of children/pet-robots interaction would contribute to evaluate the impact of pet-robots in children's lives, and to inform both robots' design and robot-based applications for health and wellbeing.

First, this research presents a novel model of bonding with robotic pets inspired in the human-animal affiliation and particularly in child-dog relatedness, where bonding is envisaged as a process towards companionship that evolves through three stages –first impression, short-term interaction and lasting relationship- characterized by distinguishable patterns of behaviors, cognitions and feelings that can be identified and measured.

Secondly, a behavioral analysis of children interacting with the Pleo robot -a robotic pet shaped as a baby dinosaur-, with an emphasis on the interactional surface and particularly on the sequences of dyad's reciprocal exchange is presented. The outcomes are twofold: the ethograms and coding schemes of Pleo's and children's behaviors and a higher level categorization of behaviors involved in bond forming that can be applied to other platforms and users.

Thirdly, a naturalistic study carried out in a pediatric hospital to observe the interactive practices with the Pleo robot *in the wild* and to evaluate the feasibility and effectiveness of a Pleo-based intervention to accompany children is analyzed and discussed. Inspired on the beneficial effects of real pets' company, the study consisted in an intensive ethnography, a systematic observation of a group play session and a follow-up case study of an experience of *adopting* a Pleo.

Our results show that the key mechanism driving bond forming is the robot's capability to deploy credible attachment behaviors –proximity seeking and resource soliciting- that elicit complementary nurturing and play behaviors in children. Beyond the novelty effect, self-reinforcing processes as learning and evolution can keep children engaged in rewarding interaction with the robot over time. Moreover, Pleo's versatility allows diverse modalities of interaction and individual and group play, satisfying different needs as company, technological curiosity, entertainment and social facilitation both for normatively developed children and for children with special needs and their families. In general, the introduction of robot-based play was regarded by the hospital professionals not only as compatible with their daily day practice but valuable as a regular resource to smooth children's stay at the hospital.

Resum

Aquesta tesi aborda el sorgiment de la implicació emocional en la interacció amb els robots socials. Més específicament, s'investiga la dinàmica de la afiliació dels nens amb les mascotes robòtiques per tal de dissenyar programes basats en robots per millorar l'experiència dels pacients en els hospitals pediàtrics. Els robots mascota imiten els animals de companyia tant en l'aparença com en el comportament. Considerem que investigar la dimensió emocional de la interacció nen/robots-mascota contribuirà a avaluar-ne el seu impacte en la vida del nens i nenes, i a informar el disseny d'aquests robots i de les aplicacions que se'n deriven per a la seva salut i benestar.

Aquesta investigació presenta en primer lloc un nou model de vinculació inspirat en la afiliació d'humans i animals, i més concretament, en la relació nen-gos, on es considera la vinculació com un procés que evoluciona a través de tres etapes –primera impressió, interacció a curt termini i relació duradora- caracteritzat per patrons de comportaments, cognicions i sentiments susceptibles de ser identificats i mesurats.

En segon lloc, s'analitza el comportament de nens interactuant amb el robot Pleo –un robot mascota en forma de nadó dinosaure-, amb un èmfasi en la superfície d'interacció i en particular en les seqüències d'intercanvi recíproc de la diada. Els resultats són de dos tipus: els etogrames del Pleo i dels nens, i una categorització a més alt nivell del comportaments que intervenen en la formació del vincle, aplicables a altres plataformes i usuaris.

En tercer lloc, s'analitza una experiència d'intervenció en un hospital pediàtric per observar les pràctiques interactives amb el robot Pleo, i per avaluar la viabilitat i l'eficàcia d'una intervenció basada en el Pleo per acompanyar els nens. Inspirat en els efectes beneficiosos de la companyia de mascotes reals, l'estudi va consistir en una etnografia, una anàlisi observacional d'una sessió de joc en grup amb el robot, i un estudi de cas longitudinal d'una experiència d'*adopció* d'un Pleo.

Els resultats mostren que l'aspecte clau que impulsa la formació del vincle és la capacitat del robot per desplegar conductes d'aferrament creïbles –cerca de proximitat i sol·licitud de recursos- que provoquen comportaments complementaris de criança i joc en els nens. Més enllà de l'efecte novetat, processos com l'aprenentatge i l'evolució del robot poden mantenir en els nens una interacció duradora amb el robot. D'altra banda, la versatilitat de Pleo permet diverses modalitats d'interacció i joc, i satisfer diferents necessitats dels usuaris, com ara companyia, curiositat, entreteniment i facilitació social, també per nens i nenes amb necessitats especials i les seves famílies. En general, la introducció del joc basat en el robot va ser considerada pels professionals de l'hospital no només compatible amb la seva pràctica professional, sinó també com un recurs valuós per alleugerir l'estada dels nens a l'hospital.

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1. Introduction

1.1. Motivation

"Although robots are starting to enter in our professional and private lives, little is known about the emotional effects which robots elicit" (Rosenthal-von der Pütten et al., 2014). From the scientific perspective, there is a necessity pointed out once and again by the Human Robot Interaction (HRI from now on) community to gain understanding about what makes *living with* robots attract and maintain our interest over time (Fernaeus, Håkansson, Jacobsson, & Ljungblad, 2010) and which are the emotional effects of this relationship (Rosenthal-von der Pütten, Krämer, Hoffmann, Sobieraj, & Eimler, 2013).

During the last decades "increasingly sophisticated personified computational artifacts that mimic biological forms and pull psychologically in mental, social and moral ways" are been deployed out of the labs (Melson et al., 2005).

In this context and from our perspective, the key question Human Robot Interaction researchers cannot longer postpone is: "are pervasive interactions with a wide array of 'robotic others' [...] a good thing for human beings?" (Melson et al., 2005). We believe that a deeper understanding of the psychosocial processes of relating to and establishing emotional bonds with social robots could significantly contribute to the debate.

Pet-robots are as a *subclass* of social robots that emulate animals of company marketed as *companions* and that are used in the emergent field of robot-based activities, including robot-assisted therapies. In fact, a wide contingent of pet-robots has already been deployed in different therapy related programs with promising results, as recent revisions on HRI research show out (Leite, Martinho, & Paiva, 2013).

However, in spite of the encouraging results and the unquestionable fascination and curiosity that these artificial creatures arise among scientists from diverse fields –sociology, behavioral and cognitive sciences, engineering, ethology, philosophy- the potential, limitations and drawbacks of pet-robots as social *partners* and particularly in therapeutic contexts are far from being clear (Melson, Kahn, Beck, Friedman, et al., 2009).

Because of this lack of scientific evidence some doubts and ethical concerns arise about the actual impact of being *exposed* to pet-robots' company, both as final users in commercial applications and as participants in studies in on-going research. These ethical issues are even more urgent to be addressed in therapy related interventions where target users belong to vulnerable profiles (i.e. infants, elderly people, patients at hospitals, and disabled people). Actually, the present work focuses on one of the most vulnerable populations: children patients at hospitals.

From the point of view of designers and practitioners, gaining understanding of the dynamics of children bonding with pet-robots would better inform the robot's embodiment and behavior design that –hopefully- would result in an *optimal* degree of children's emotional involvement with these artificial creatures.

Furthermore, a deeper knowledge of individual and situational variables influencing bond emergence and maintenance would help to identify the more suitable situations and contexts to plan effective interventions (Melson, Kahn, Beck, Friedman, et al., 2009). Doing so, the compelling attraction these artificial creatures exercise on humans would be efficiently applied to enhance children development and health while avoiding undesirable side effects.

On the other hand, the suitability of pet-robots as *subrogates* of animals of company in assistive and therapeutic *missions* is controversial -and even rejected in some scientific communities- and it is necessary to gather empirical evidence to evaluate thoroughly and critically the impact of these appealing creatures on children *before* their massive adoption.

Provided animals have long been an important part of children's lives, offering comfort and companionship, and promoting the development of moral reciprocity and responsibility (Melson & Fine, 2010) two questions arise: can robotic pets, compared to biological pets, provide children with similar developmental outcomes? (Kahn, Jr., Friedman, Pérez-Granados, & Freier, 2006) Might children benefit from the company of pet-robots as they benefit from animal assisted programs for health and wellbeing?

1.2. Object of Study

The object of study of this dissertation is the social bond that people eventually establish when interacting with social robots. Specifically, the focus of this research is the emotional bonding between children and pet-robots.

Definition

We envisage this bond as a social dyadic link with a strong emotional component between people and *personified technologies* that emulate pets. Pet-robots are social robots that embody interactive and adaptive computational technology in shapes that mimic the biological entities like cats or dogs (Melson G. F., Kahn Jr, Beck, & Friedman, 2009).

Delimitation

Human-robot bonding has a more restricted meaning than the overarching concept of human-robot *interaction,* that encompasses any *specific communicative act* (Krämer, Eimler, von der Pütten, & Payr, 2011) or sequence of behaviors between the individual and the robot in a particular social situation (*encounter*). Differently from the generic concept of interaction, bonding is defined as the emotional relatedness that unfolds over time.

The focus of this research is in the *interactional surface* of child-robot sociality (Pitsch & Koch, 2010; R. Gehle K. Pitsch, 2017). In depth investigation on human and robots' underlying processes (i.e. psycho-biological and computational respectively) is beyond the scope of this work. Thus, the present dissertation addresses neither the computing (i.e. software engineering, artificial intelligence) nor the technical implementations (i.e. mechanical structure, sensing and actuation elements, communication systems) underpinning robots' morphology and performance.

In spite its undeniable interest, the present work does not deal either with the computing implications of adding sociality to robot's rationale. Recent approaches in Artificial Intelligence -*social intelligence hypothesis* (Kerstin Dautenhahn, 2007b, 684)- introduces social competences as a means to improve robots' cognition (i.e. perception, learning and decision making) mimicking -or being inspired by- animal or human intertwined cognitive-emotional processes (Moussa & Magnenat-Thalmann, 2013).

Assumptions

- People build social and affective bonds not only with other people but also with other biological non-human partners (e.g. animals of company) and with artificial partners such as social robots (Melson, Kahn, Beck, Friedman, et al., 2009).

- To study and understand the bond with social robots we can apply the available knowledge –both substantial and methodological- of interpersonal bonds, bonds between social animals, and human relatedness with animals (Melson, Kahn, Beck, Friedman, et al., 2009).
- In a social situation defined by the complementary roles of owner-pet, some robot's features and/or behaviors would elicit in the child the perceptions, behaviors and emotions related to the role of owner/keeper.
- Under certain conditions, pet-robots' company may be beneficial for children emotional wellbeing in a similar way that biological pets are.

Keywords

Children-Robot Interaction, Robotic Pets, Companion Robots, Bonding, Attachment, Robot-Based Programs for Health and Wellbeing.

1.3. Purpose and Objectives

The ultimate goal of this research is to gain understanding of the dynamics of children's bonding with pet-robots and to draw empiric-based guidelines to implement assistive programs based on children's social rapport with companion robots.

The research questions belong to different levels of knowledge. The first one deals with the description of the bond in terms of its manifestations. The second one addresses the relationship between individual and situational factors with the dynamics of this bond. The third one focuses on the eventual impact of the bond building on the desired therapeutic-related goals.

The goals linked to these three questions are:

P1 What is the behavioral manifestation of child's bond with a pet-robot?

- Describe the bond with social robots in terms of behavior, perceptions and subjective experience
- Describe a standard pattern in the dynamics of affective bond forming with social robots identifying states and transitions
- Observe this process in the wild in the course of a robot-based intervention in a pediatric hospital

P2 Which factors influence the emergence of an affective link with a pet-robot?

- Inspired in the human-animals bonding, identify which features of the pet-robot's appearance (embodiment) and behavior are relevant in the establishment and maintenance of the emotional link.

- Identify key children's interactive practices and dyadic episodes that reinforce the emergence/maintenance of the bond.
- Identify the individual and contextual variables that influence bond emergence

P3. Does the interaction with pet-robots improve children experience during hospitalization? If it were the case, under which conditions would this companionship be effective?

- Analyze a pet-robot based intervention in a pediatric hospital to study children-pet robot interaction and bonding in the wild, with an emphasis on the compatibility with the professionals' practices, the effect on users and the dynamics of appropriation.
- Establish evidence-based guidelines to monitor the emergence of an optimal affective bond between children and the pet-robot in the context of a health-related intervention.

1.4. Methodological Approach

In this section we explicit the methodological approach adopted according to i) the nature of the object of study, ii) the research questions, iii) the purpose and the specific application context, and last but not least v) the epistemological assumptions.

This overall methodological approach will be complemented by the specific design and methods applied in the empirical work in Sections 4 and 5, devoted to children-Pleo interaction analyses and the case study in the pediatric hospital, respectively. Pleo is a baby-dinosaur shaped pet-robot marketed as an electronic toy (see Fig. 3-1).

We understand child-robot bond forming as a socio-psychological process that conforms to identifiable patterns of interactive behaviors with and perceptions and feelings towards the robot. These patterns are context and platform dependent and highly influenced by individual and situational variables. Moreover, we consider that these behaviors and perceptions can be modified and in turn influence the therapeutic-related outcomes.

The main features of this research that inform the methodological choices are:

i. The object of study is a complex social process that involves both biological and artificial creatures and unfolds in observable behaviors.
ii. The goal is to gain understanding of whether, how and why children relate to pet-robots over time.
iii. The ultimate purpose is to apply this knowledge to support children in hospital with pet-robots' company.

Taking these assumptions into account we adopt a holistic and ecological multi-method approach, with preference for the qualitative methodology and the observational techniques, with an emphasis on the context and on the episode as an analysis unit.

See Sections 4 and 5 for further elaboration on specific research designs, methods and techniques adopted in the empiric research.

1.5. Expected Contributions

1. An integrative revision and elaboration of the State of the Art highlighting the current gaps and challenges of social HRI and the confluence and interrelatedness of different scientific domains. In the case of the present dissertation we dare consider that the investigation and systematization of literature and antecedents is not just an unavoidable revision of previous work but a contribution in itself being social HRI an emergent discipline.

2. An original proposal of a developmental and dynamic model of bonding with pet-robots based both on empirical studies and on the current knowledge from the fields of HRI, social psychology, ethology and design.

3. A method for describing, assessing and modeling bonding with pet-robots in a way that facilitates the accumulation of empiric evidence and knowledge according to the scientific standards in this field.

4. A data-driven behavioral system and a coding scheme for observational studies on child-pet-robot interaction *customizable* to different contexts and platforms.

5. A multi-method case study of pet-robot interaction over time in a pediatric hospital

6. Guidelines to inform pet-robots' appearance and behavior design.

7. Guidelines to design pediatric related programs based on pet-robots' company.

1.6. Outline of the Dissertation

The dissertation is organized in 5 blocs:

1. Introduction
2. State of the Art
3. A dynamic model of child-robotic pet dyad performance over time
4. An observational analyses of children-Pleo interaction
5. A case study of intervention with Pleos accompanying children in a pediatric hospital
6. Discussion, conclusions and further work.

In Chapter 1 the purpose, objectives, theoretic framework, methodological approach, research questions, scope and main expected contributions are exposed.

In Chapter 2 the state of the art is unfolded beginning with the more general areas in three sections: relatedness with robots, bonding with companion robots in general and with pet-robots in particular, and using companion robots for therapy related interventions with children. This chapter ends with a reference to the dissertation's expected contributions within this conceptual framework.

In Chapter 3, first a characterization of the child/pet-robot dyad is developed, integrating the knowledge available from different disciplines and providing an explanatory framework inspired in the human-animal bond (HAB) and more specifically, in child-dog relatedness. Secondly, a novel model to represent and explain the dynamics of bond formation with companion robots is presented.

In Chapter 4 a categorization and analysis of child-Pleo behavior is exposed. This chapter encompasses the construction and application of an ethogram of the robot's behaviors and an inventory of children interactive behaviors with the robot, based on video-recorded episodes from pilot studies.

In Chapter 5, the model and methodological instruments developed in Chapter 3 and 4 are applied to an intervention in the wild where a *fleet* of robots is deployed in a pediatric hospital to accompany and support children during their stay.

In Chapter 6 the findings and results drawn from the empirical studies carried out are discussed.

Finally, Chapter 7 presents the overall conclusions and Chapter 8 addresses the limitations of this work and contemplates further developments.

2. State of the Art

Human interaction with robots –and specifically social interaction with robots- is an emergent research field (Kerstin Dautenhahn, 2007b, 683) with short tradition and intrinsically interdisciplinary. As stated by Dautenhahn several years ago "as a research field HRI is still in its infancy" (2007a, 103).

There is a wide consensus that the theoretical and methodological framework of social robotics is still under construction after a couple of decades of development.

Although the scientific research on the social dimension of robots' performance is rooted on artificial intelligence and robotics disciplines, HRI community assumes its complex nature at the intersection of engineering, psychology, artificial intelligence, cognitive science, social sciences, linguistics, computer science, ethology and human-computer interaction (Kerstin Dautenhahn, 2007a, 103; 2007b, 683). The design of a robot's behavior, appearance, cognitive and social skills is scientifically highly challenging and requires interdisciplinary collaborations across the traditional boundaries of established disciplines (K. Dautenhahn, 2004).

In particular, HRI is a human-centered robotics discipline that necessarily places humans and how they experience interaction *in the loop*. Differently from traditional engineering and robotics, interaction with people is a defining core ingredient of HRI, comprising social psychological processes and competencies such as verbal and/or non-verbal communication (Kerstin Dautenhahn, 2007b, 683).

As stated Arkin fifteen years ago referring to entertainment robots but applicable to personal robots in general:

> Human-robot interaction is of critical importance in the entertainment robotics sector. In order to produce a desirable end product that can be enjoyed for extended periods of time, it is essential that an understanding of not only robotics but also human psychology be brought to bear. (Arkin, Fujita, Tagaki, & Hasegawa, 2002)

Nowadays, current topics in HRI research overlaps social and behavioral sciences interests, such as emotional reactions towards robots appearance (e.g. anxiety towards robots, empathy); expectations about robots functionalities; the influence of personality traits in the attitude towards robots; the relationship between a robot's perceived personality and the level of user control (Kerstin Dautenhahn, 2007a, 107; 2007b, 684).

In addition to psychology and linguistics other disciplines such animal behavior, human-animal interaction and ethology has been extensively and enthusiastically considered by the HRI community as most inspiring disciplines to inform HRI developments (Arkin et al., 2002; Arkin, Fujita, Takagi, & Hasegawa, 2001; K. Dautenhahn, 2004; F Kaplan, 2001; Koay et al., 2013; Takahashi, Márta, Korondi, Hashimoto, & Niitsuma, 2015).

> ...designers and researchers are also exploring potential interaction modalities that human users may be familiar with from human-animal interactions [...] we therefore explored other modalities with the aim to complement and improve the design of behaviors for social robots. Human dog interaction is one of the interaction modalities we are particularly interested in since dogs have been known to be reliable companions for humans. (Koay et al., 2013, 90)

The present chapter is organized starting by the more general debate on the essence of sociality and the potential *niche* –if any- of companion robots and robotic-pets in our lives. Secondly, the review addresses particular technological and methodological challenges and ethical issues when designing and deploying robots in strategic services as children health-care. Finally, this chapter ends with the expected contributions of the present dissertation, with regard to the challenges and gaps identified in the state of the art revision.

In particular the topics addressed are:

- The concept of sociality with robots is reviewed as a particular instance of human affiliation with non-biological partners. Open questions on the ontological and social status of these *non-biological others* in the frontiers of animate and inanimate worlds and their potential impact on our societies are faced as well. Implications and ethical concerns on human relationships with these creatures we are confronted with are briefly addressed.
- Theoretic frameworks and models adopted to study and explain the interaction and relationship with robots are reviewed. The ethological approach as a promising – although controversial- alternative to more conventional models drawn from interpersonal relationships studies is elaborated in the light of the lively debate in HRI community on which one is more suitable to inform social robots developments.
- Literature and antecedents on companion robots research, focusing on pet-robots as a subclass with specific features, potentials and limitations.
- Literature and antecedents on bonding with companion robots with special emphasis on gaps and challenges reported by researchers. We give special attention to the accumulated knowledge on child-robot interaction and to therapeutic interventions based on the long-term relationship with robots.

Our emphasis in this State of the Art is given to integrate approaches, methods and relevant findings produced in different –and sometimes distant- scientific domains. Our sources can be classified as follows according to the discipline involved and the specific topics:

Human-Robot Interaction

- Child-robot interaction
- Long-term interaction
- Pet-robots
- Emotionality in HRI

Social and Development Psychology

- Interactive behavior and verbal and non-verbal communication
- Bond forming and relationships dynamics over time
- Methods and techniques to study and model dyadic relationships and its dynamics
- Theory of Mind
- Development studies on perceptions, cognitions, attributions and judgments on animate/inanimate entities and biological/artificial creatures.
- Methods, techniques and ethics in childhood and early childhood research

Ethology, Animal Behavior, Human-Animal Affiliation

- Interactive behavior and relationship between people –specially children- and animals
- Bond forming with pets
- Pet behavior to inform the appearance and behavior for credible pet-robots design (bio inspiration).
- Systematic observational studies –in the wild and in experimental settings- on owner-pet –mostly dog- dyad behavior (e.g. attachment, social monitoring, synchronization).
- Questionnaires and scales and other instruments to measure the person-animal bond.
- Ethological approach to the functionality of behavior and specially –for our interest- the social behavior.
- A preference for the ecological approach in behavior analyses and observational methods in the wild (i.e. non-manipulated environments)

- The use of ethograms and behavioral systems as a tool to understand and measure interactive behavior between people and robots.
- Critical consideration of the implications and potential detrimental impact of the proliferation of artificial pets on our relationship with the natural world.

Social Studies of Science and Technology

- Critical analyses of how living with personified technologies affects our society's believes and values on socialness and subjectivity and redefines the essence of natural and artificial worlds.
- Discussion and judgments -including ethical issues and detrimental impact- on these technologies being adopted in therapy and educational programs and mediating more and more pervasively our contact with others.

2.1. Relatedness with Robots

Our relationship with objects –technology- has been the object of scientific disciplines for several decades. Ergonomics in particular (or Human Factors we will use the terms indistinctly) addresses the engineering of the quality of use of objects, systems, environment, with an emphasis to adapting the system to the user's bodies, needs, capabilities and preferences basically but not only in their physical dimensions like size and shape. According to the progressive prevalence in our lives of information-based systems, ergonomics extended their field to include prominently the cognitive requirements of use (cognitive ergonomics: Rasmussen & Jens, 1986) and even the emotional dimension of user's experience (Norman, 2004; Picard, 1997, 2001) both in working systems and in every day products' design. Without neglecting the dimensional adaptation to users, the interest shifted into the cognitive and emotional mechanisms involved in interacting with *smart* technology and the outcomes include as well psychological variables such as engagement, enjoyment, pleasure or trust.

Nevertheless, in spite of the huge evolution experimented by the objects we have been using (including robots) in industrial and everyday environments, we can consider that the quantum leap occurred when a class of these common use objects become not only intelligent but also social: objects that call not only to be used but to be socially interacted. In the case of social agents –digital or embodied- the paradigm of tool-use are changed into the paradigm partner-sociality. Consequently, the engineering of compliant social robots based systems has turned to the disciplines that provide the required knowledge about human socialness: psychology, sociology, ethology, linguistics and philosophy –among others. According to the International Ergonomics Association (http://www.iea.cc/) ergonomics' goal is the understanding of interaction among humans and *other elements* of the system. Until recently, one took for granted that the other elements of the system were objects, but now the frontiers are blurring and smart systems would require taking into account the ways users affiliate and socialize with their artificial partners.

2.1.1. Affiliation with Non-Biological Entities

There is a most interesting debate from the Social Studies on Science and Technology field on how we regard the animated non biological entities and how we judge them according to the conventional ontologies, and whether and to which extent they caracterize a new specie in the frontiers of machines and animated beings (Pfadenhauer, 2013). These entities go beyond the alive and inert distinction and blur the lines of social agency that traditionally was attributed exclusively to biological entities. Entities that feature a great agency capability question this categorizations and believes promoting new ontological considerations and a new way to think about and interact with non-living creatures.

> An extensive body of research regarding the sociality of reactions towards artificial entities such as computers, virtual agents and robots coherently showed that people treat these artificial entities like real people and apply the same social norms and rules they use in HHI. (Rosenthal-von der Pütten et al., 2014)

Even though there is considerable empirical evidence indicating that humans have a natural proneness to affiliate with life (the *biophilia hypothesis* (Kellert & Wilson, 1993), what is still an open question is "to which extend this affiliation extends to robotic analogies of animal life, to those artifacts that emulate the shapes and processes of life" (Melson, Kahn, Beck, Friedman, et al., 2009).

It is assumed that this proneness to affiliate and bond -showed by humans and other species- is related to the satisfaction of the need to belong (Krämer et al., 2011, 490) and extends beyond the biological entities including other designed entities, some of them, as social robots, deliberately designed to engage us in closeness.

As artifacts are progressively taking roles played in people's close proximity, providing strategic personal services -assistence, coaching or education-, steps have to be taken to enable a blending of these systems into people's lives. To achieve this eventual harmonious cohabitation with artificial partners, the essential challenge is to feature them with smart sociability (Krämer, Eimler, von der Pütten, & Payr, 2011).

Provided social behavior encompasses interactive behavior between individuals of the same and different species -that not share genetical identity (e.g. human with horses or dogs)-, the concept of inter-specific sociality can be easily extended to human-artifact or human-agent interaction, that could be characterized as well as *social* (Miklósi & Gácsi, 2012).
Kahn, from his studies on children and adults behavior with and perceptions towards robots, dares to assert:

> …a new technological genre may be emerging that challenges traditional ontological categories (e.g., between animate and inanimate). This genre comprises artifacts that are autonomous (insofar as they initiate action), adaptive (act in response to their physical and social environment), personified (convey an animal or human persona), and embodied (the computation is embedded in the artifacts rather than just in desktop computers or peripherals). (Kahn, Jr. et al., 2006, 430)

2.1.2. Social Robots

2.1.2.1. The Concept

Social robotics is a rapidly emerging field aiming at design robots that can be immersed in human social networks and are able to interact with humans in a meaningful way (Kerstin Dautenhahn, 2007b; Fong, Nourbakhsh, & Dautenhahn, 2003).

> Since humans are social beings we can assume that the usability of robots improves if they also have social capabilities. (Lohse, 2010)

Socially interactive robots, *social robots* or *relational artifacts* are robots that provide their services -entertainment, education, therapy- interacting socially with the users (Fernaeus et al., 2010). In this sense *sociality* is a modality of communication, a specific mechanism to support different functions (e.g. companionship, coaching, and assistance).

Fong described the main features of social robots in terms of their interaction with humans, noting that such robots need to rely on humans' tendency to anthropomorphize, have to be reactive to the human behavior and at the same time be able to initiate social interactions with humans. More precisely, listed some *human-like* behavioral and cognitive traits that such socially interactive robots should feature: perception and expression of emotions, high-level communication skills, recognition, establishment of social relationship with humans, use of human-like behaviors (ex. gesturing) and showing *personality's traits* (Fong et al., 2003).

> Once people can no longer distinguish a robot from a persona, a goal that is being pursued in the field of Androids, then people will treat them like humans. (Kerstin Dautenhahn, 2007a, 104)

Kahn et al describe social robots as "robots that, to varying degrees, have some constellation of being personified, embodied, adaptive, and autonomous; and that can learn, communicate, use natural cues, and self-organize" (Kahn, Jr. et al., 2006 citing Fong et al, 2003). According to Dautehhahn, social robots are –or should be- *essentially* socially evocative, socially situated, sociable, socially intelligent and socially interactive (Kerstin Dautenhahn, 2007b, 684) (see Fig. 2-1).

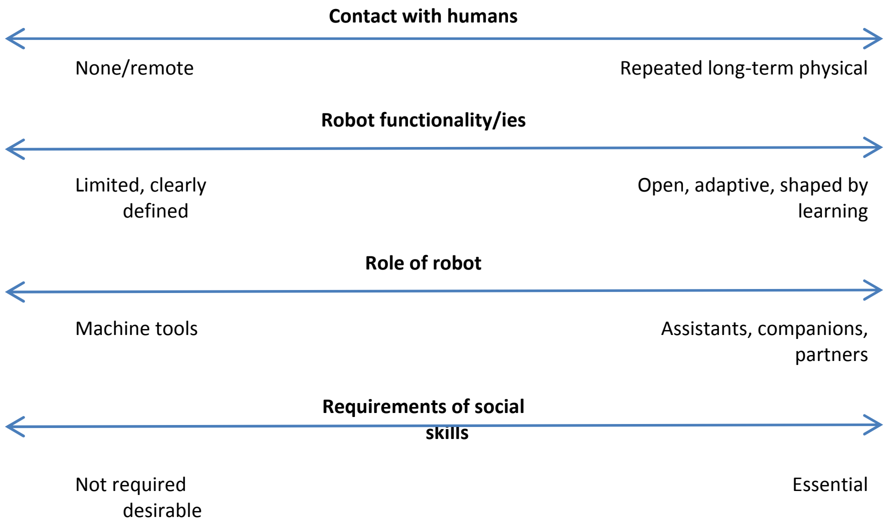


Figure 2-1 Evaluation criteria to identify requirements on social skills for robots in different application domains (Kerstin Dautenhahn, 2007b, 683).

The main interest of HRI community in defining *social compliant* behavior is to derive guidelines to implement robot's behavior and the corresponding validation criteria.

From another point of view, Marti (2005) places the essence of a social robot on what it is capable to elicit in humans, rather on a list of traits and skills.

> Such systems are not designed to help the human being performing work tasks or saving time in routine activities, but to engage them in personal experiences stimulated by the physical, emotional and behavioral affordances of the robot. (Marti, Pollini, Rullo, & Shibata 2005)

Similarly, from a functional perspective, Miklósi put the emphasis of robots' smart interaction to the effect on user, instead of on particular technological capabilities.

> Considering the efficiency and believability of a social interaction between robot and man, it is not essential that the robot has the underlying cognitive capacity for a particular skill but rather that it should appear to have it. (Á. Miklósi & Gácsi, 2012,8)

2.1.2.2. *Density* of Social Robots in Our Lives

According to the International Federation of Robotics predictions on global robot market between 2016 and 2019, 42 million service robots for personal and domestic use (consumer robots) will be used in our private life (personal and domestic use), encompassing housekeeping (vacuum and floor cleaning and lawn-mowing), entertainment and leisure robots, and robots for elderly and handicap assistance (International Federation of Robotics, 2016).

As for entertainment robots, about 1.7 million units were counted in 2015, 29% more than in 2014. Numerous companies, especially Asian ones, offer low-priced *toy robots*. But among those mass products, there are increasingly more sophisticated products for the home entertainment market. Service robot suppliers already estimated in 2010 a strong increase of sales of robot companions/assistants/humanoids. But now, it is projected that between 2016 and 2019 some 8,100 units of these robots will be sold. However, until now, there have been no significant sales of humanoids as human companions to perform typical everyday tasks in production, office or home environments. Quite a few Japanese companies (Honda, Kawada, Toyota and some others) and also American, Korean and European companies are in the process of developing these general-purpose robot assistants beyond the toy and leisure stage. First shipments of these humanoid robots started in 2004 to international laboratories and universities as high-end robotics research and development platforms. So, this forecast seems to be realistic for the period between 2016 and 2019 especially given the recent successes in this field.

The size of the market for toy robots and hobby systems is forecast at about 8 million units, most of which for obvious reasons are very low-priced. About 3 million robots for education and research are expected to be sold in the period 2016-2019. Sales of robots for elderly and handicap assistance will be about 37,500 units in the period of 2016-2019, this particular market is expected to increase substantially within the next 20 years.

Along with social robots' market expansion and the penetration of personal robots, EU citizens also have well-defined views about the desirable *density* of service robots in our society, according to the 2012 Eurobarometer on *Public Attitudes towards Robots*. with regard to the application areas for robots and the areas in which the use of robots should be banned European citizens consider they should be used as a priority in areas that are too difficult or too dangerous for humans, like space exploration (52% priority), manufacturing (50%), military and security (41%) and search and rescue tasks (41%); there is widespread agreement that robots should be banned in the care of children, the elderly or the disabled (60%) with large minorities also wanting a ban when it comes to other 'human' areas such as education (34%), healthcare (27%) and leisure (20%) (European Comission, 2012).

2.1.2.3. (Why) Do We Want Social Robots?

Kaplan contributes with a different perspective of the presence of artificial creatures in our worlds, wondering why they are not been adopted massively:

> Why are we not living yet with robots? If robots are not common everyday objects, it is maybe because we have looked for robotic applications without considering with sufficient attention what could be the experience of interacting with a robot. (F Kaplan, 2005, 59)

Assuming that technology is not neutral, in this section we review briefly the main motivations to assign important financial and scientific resources (see Table 2-1) to develop social robots that can shed light on –from the functional point of view- the interests at stake in the current and future trends of the expansion of this discipline.

Research

There is an enormous curiosity in investigating the boundaries of humanness, the nature of socialness and the underlying psychological and social processes that support sociality in both directions. On one hand, from the technology perspective the challenge to emulate nature and the most complex outcomes in terms of human intelligence and adaptive capabilities and push the limits of technology to reach life-likeness creatures. On the other, from behavioral sciences, the possibility to recreate embodied models that reproduces with higher and higher fidelity human and animal capabilities is an opportunity to have a new approach –from the inside- to the *black box* of behavior.

In addition, studying centric psychological and social constructs -such as attachment, perceptions, judgments- in artificial creatures, shed new light on what is essential in our conceptualization and relatedness with human, nature and technologic worlds, and how concepts and attributions reserved to human or to biological entities should be extended to other agents, and the way people and societies manage to understand and integrate new realities when challenged with new creatures that no longer fit into ancestral deep rooted ontological believes. Social robots are an incomparable test bed for developmental, social, cognitive, neuroscience researchers and ethologists and let alone for sociologists and science and technology scholars. Therefore, robotics and behavioral sciences feed each other with new insights and techniques to impulse investigation in their respective domains.

Table 2-1 summarizes a selection of European Funded Research Projects on Social Robotics indicating the interests, topics and focus of funded research in the last 10 years.

Going a step forward, Paul Baxter affirms:

> [...] the use of robotic agents, and particularly the behavior of those agents, to examine theoretical problems from the animal sciences is an established success. Indeed, it has been suggested that the ultimate aim of artificial agent research is to contribute to the understanding of human cognition. (https://paul-baxter.blogspot.com.es/2008/02/sort-note-on-artificial-ethology.html).

From the perspective of Artificial Intelligence (AI) development, it is interesting to point out that social human-robot interaction is in the agenda of HRI researchers not only as a necessary *add-on* to human-robot interfaces for acceptable and smooth communication but also as a way to make robots more intelligent (social intelligent hypothesis). To some extend robots' sociality is something people appreciate for smooth interaction in many services contexts but also is a capability robots need to become more intelligent (Kerstin Dautenhahn, 2007b, 682).

> Researchers may be motivated differently to join the field HRI. Some may be roboticists, working on developing advanced robotic systems with possible real-world applications, e.g. service robots that should assist people in their homes or at work, and they may join this field in order to find out how to handle situations when these robots need to interact with people, in order to increase the robots' efficiency. Others may be psychologists or ethologists and take a human-centered perspective on HRI; they may use robots as tools in order to understand fundamental issues of how humans interact socially and communicate with others and with interactive artifacts. Artificial Intelligence and Cognitive Science researchers may join this field with the motivation to understand and develop complex intelligent systems, using robots as embodied instantiations and test beds of those. (Kerstin Dautenhahn, 2016)

Applications Substituting Manpower in Weak Jobs

Services robots living with people developing the domestic and caring could eventually substitute manpower (the so called *weak subjects*) (Fortunati, 2013) under certain conditions in housekeeping, assistance, receptionists or caring. In this cases, acceptability, safety and effectiveness of human-robot communication is crucial, being services delivered in face to face situations and that implies closeness, easiness and trust.

> Without a wide range of social skills the robots will not be used· so they would fail in their role. (Kerstin Dautenhahn, 2007b, 683)

Military Purposes

Social robotics open a wide range of military applications and a growing body of research has refocused attention from traditional human factors engineering –it is interesting to remember that human factors development was in line with the sophistication of machines and specially weapons with increasing complexity and demand on human operators- to understand the interactions of humans and robots.

> A particular objective of this research has been the development of a fundamental understanding of how humans and autonomous machine agents can operate efficiently as teams to accomplish mission objectives and share in tasks in a way that the differing abilities of the humans and machines are used to best advantage. Research funding agencies in the United States are taking an increasing interest in the operation of mixed teams of humans and robots. In part this interest has sprung from the U.S. government mandate that by 2015 a third of all deployed military vehicles must be autonomous. It is anticipated that future teams will feature significant changes in the decision-making roles of the robot and human team members. (Baillieul & Kunikatsu Takase, 2008)

Humanity Centered Robotics

Recently a new approach to enhance the humanistic values on HRI research and applications is gaining support, claiming that HRI can be and should be societally beneficial beyond pursuing the goal of technological advancement *per se*. To ensure that these advancements –and robotics in particular- are applicable and beneficial economically and socially the researchers in robotics should orient to the social impact. We want to point out here the importance that this initiative come from inside the HRI community, what most probably can amplify the impact of a critical approach more than the analyses that come from *outside* such us the science and technology studies that though necessary maybe has a smaller capability to influence the course of the technologic developments.

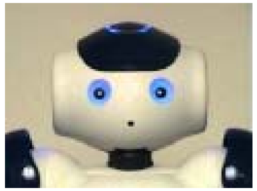
In this sense we want to highlight the *Humanity Centered Robotics Initiative* at Brown University at Providence, Rhode Island, that present their main focus on interdisciplinary and their commitment to the social accountability of technological developments.

> We are working across many disciplines to document the societal needs and applications of human-robot interaction research as well as the ethical, legal, and economic questions that will arise with its development. Our research ultimately aims to help create and understand robots that coexist harmoniously with humans.

Common commitments include (a) identifying societal needs that robots can help fulfill; (b) advancing science and technology of robots that fulfill these needs; and (c) studying and integrating into design the societal impact of robotic technologies, with a goal of averting labor replacement and privileged access to technology. (https://hcri.brown.edu/)

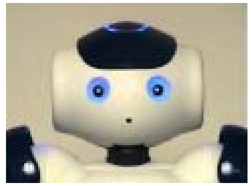
Table 2-1 Selected European funded research projects on social robotics

Logo and Web Site	Name	Description	Platform	User/Context
http://www.robot-era.eu/robotera/ 2012-2015	**ROBOT-ERA** *Implementation and integration of advanced Robotic systems and intelligent Environments in real scenarios for the ageing population*	Develop, implement and demonstrate the general feasibility, scientific/technical effectiveness and social/legal plausibility and acceptability by end-users of a plurality of complete advanced robotic services, integrated in intelligent environments, which will actively work in real conditions and cooperate with real people and between them to favor independent living, improve the quality of life and the efficiency of care for elderly people.		Elderly - Male and female over 65 years old - With moderate health problems and motor and cognitive deficits - Living alone or with their relatives but without a devoted caregivers.
http://dream2020.eu/ 2014-2018	**DREAM** *Development of Robot-Enhanced therapy for children with autism spectrum disorders*	Driven by therapists, DREAM will deliver next-generation RET, developing clinical interactive capacities for supervised autonomy therapeutic robots and will also function as a diagnostic tool by collecting clinical data on the patient. It will operate under strict ethical rules and the DREAM project will provide policy guidelines to govern ethically-compliant deployment of supervised autonomy RET.	Nao & Probo 	Children with ASD, therapeutic programs

Logo and Web Site	Name	Description	Platform	User/Context
 http://www.aliz-e.org/ 2010-2014	**ALIZ-E** *Adaptive Strategies for Sustainable Long-Term Social Interaction*	Embodied cognitive robots capable of maintaining believable any-depth affective interactions with a young user over an extended and possibly discontinuous period of time, initiating and evaluating these methods in a succession of integrated systems that interacts with hospitalized children. The theory and practice of ALIZ-E will impact on theoretical cognitive systems research (e.g., memory, long-term affective interaction), implementation (e.g., cloud computing for cognitive systems, speech processing for young users) and ultimately commercial applications of these technologies.	**NAO** 	In-patient children undergoing diabetes treatment Hospital
 http://www.companionable.net/ 2008-2012	**CompanionAble** *Integrated Cognitive Assistive & Domotic Companion Robotic Systems for Ability & Security*	Provide the synergy of Robotics and Ambient Intelligence technologies and their semantic integration to provide for a care-giver's assistive environment of persons suffering from chronic cognitive disabilities prevalent among the elderly.	**Hector** The Companion Robot 	Elderly people Home and nursing homes

Logo and Web Site	Name	Description	Platform	User/Context
http://accompanyproject.eu/ 2011-2014	**ACCOMPANY**	The ACCOMPANY system will provide physical, cognitive and social assistance in everyday home tasks, and will contribute to the re-ablement of the user, i.e. assist the user in being able to carry out certain tasks on his/her own.	**Care-O-bot®** 	Elderly people Home
http://www.frogrobot.eu/ 2011-2014	**FROG** *Fun Robotic Outdoor Guide*	Develop a guide robot with a winning personality and behaviors that will engage tourists in a fun exploration of outdoor attractions.		Visitors in public outdoors facilities
http://project-sera.eu/ 2009-2010	**SERA** *Social Engagement with Robots and Agents*	Advance science in the field of social acceptability of verbally interactive robots and agents, with a view to their applications especially in assistive technologies (companions, virtual butlers).	**Nabaztag** 	

Logo and Web Site	Name	Description	Platform	User/Context
LIVING WITH ROBOTS AND INTERACTIVE COMPANIONS http://lirec.eu/people 2008-2012	**LIREC** *Living with Robots and Interactive Companions*	How we live with digital and interactive companions. Exploring how to design digital and interactive companions who can develop and read emotions and act cross-platform	**Pleo, NAO. others**	Many
http://www.aurora-project.com/ 2004-2006	**AuRoRA**	Studies if and how robots can become a "toy" that might serve an educational or therapeutic role for children with autism.	**Caspar, others** 	Children with ASD
http://www.iromec.org/ 2006-2009	**IROMEC** *Interactive RObotic social MEdiators as Companions*	Investigate how robotic toys can provide opportunities for learning and enjoyment. The developed robotic system will be tailored towards becoming a social mediator, empowering children with disabilities to discover the range of play styles from solitary to social and cooperative play.		Children who are prevented from playing, either due to cognitive or multiple impairments which affect their playing skills

Logo and Web Site	Name	Description	Platform	User/Context
http://www.ksera-project.eu/ 2010-2013	**K-SERA** *Knowledgeable Service Robots for Aging,*	Develop a socially assistive robot that helps elderly people, especially those with Chronic Obstructive Pulmonary Disease (COPD), with their daily activities, care needs and self-management of their disease.	**Nao** 	Elderly people Elderly people with chronic diseases
http://www.florence-project.eu/ 2010-2013	**Florence** *Multi-Purpose Mobile Robot for Ambient Assisted Living*	Improve the well-being of elderly (and that of his beloved ones) as well as improve efficiency in care through AAL services.		Elderly people

Logo and Web Site	Name	Description	Platform	User/Context
MONARCH http://monarch-fp7.eu/ 2013-2015	**Monarch** *Multi-Robot Cognitive Systems Operating in Hospitals*	MOnarCH targets (i) the development of a novel framework to model mixed human-robot societies, and (ii) its demonstration using a network of heterogeneous robots and sensors, in the pediatric area of an oncological hospital.	**MBot** 	In-patient Children in an oncological hospital.

2.1.3. Models of Human-Robot Sociality

Two competing models for understanding and design HR sociality have being supported by social robots' researchers: *human communication* paradigm and the *human-animal interaction* approach.

> ...beyond addressing actual interaction and communication, the nature of the relationship and the role of the companion is discussed: we will comment [...] whether the relationship to the companion should resemble an intimate long-term human-human relationship (e.g., family member, close friend) a non-intimate long-term human-human relationship (e.g. neighbor, mailman) or be based on human-pet relationship". (Krämer et al., 2011)

2.1.3.1. Interpersonal Model

Mainstream social robotics is focused overwhelmingly on producing human-like social creatures. Psychological theories play a major role in this field and it is implicitly assumed that in the case of social interactions, humans should show strong preference toward those who are like them. (Miklósi & Gácsi, 2012)

Assuming this belief, researchers and developers place a particular emphasis on the human-likeness, both in terms of embodiment and behavior. For instance, in (Kerstin Dautenhahn, 2007a) *naturalness* is equivalent to *human-likeness* and in (Lohse, 2010, 19) socialness is clearly and intrinsically restricted to interpersonal behavior: "the robot is social because it interacts with means that the users know from human-human interaction (HHI)".

Following this rational, enhancing natural communications with robots implies enhancing human-likeness in communication as if sociality with robots is restricted to sociality with anthropomorphic robots. These human-like communicative skills encompasse gestures communication, interaction kinesics, posture, social spaces managing, facial expressions, linguistic communication and dialogue, features which are hoped to provide a "*natural interface* in applications requiring direct communication between humans and robots" (Kerstin Dautenhahn, 2007a, 106).

According to the common assumed key skills for an effective social robot (Fong et al 2003), socially interactive robots that are successfully accepted and eventually adopted by human communities should show (and/or develop) human-like social competencies (Sciutti & Sandini, 2014).

Relational closeness in human dyadic interactions provides a well sounded framework for designing relational closeness with robots. The advanced simulation of relational acts by a very a human-like body will provoke genuine interpersonal experiences in humans, such as relational dimensions communicated mainly nonverbally such as intimacy and involvement, status and dominance, and emotional valence (Lee, Hope, & Witts, 2006).

From our perspective the weaknesses of the Human-Communication paradigm are not minor: i) the claim that the more human-likeness the better is more an intuitive belief than an empirical-driven knowledge –in fact the evidence from the *uncanny valley* model seems- although far from definite- to be against, ii) even if the human-likeness was the goal, current technology is lights years (Miklósi & Gácsi, 2012)from produce natural human-human communication and let alone lasting relationships, and last but not least iii) even if developing robots with full interpersonal compliant performance come up to be feasible and effective, would it be desirable?

2.1.3.2. Ethological and Animal Behavior Approach

The basic statement supported recently by researchers on the field of HRI with a strong background on ethology and animal behavior can be shortly expressed as "social robots should draw more on the insights of ethology" (Miklósi & Gácsi, 2012)

> A closer look at human-animal interaction, especially the detailed investigation of the social relationship between humans and dogs, may provide important insights for social robotics. (Á. Miklósi & Gácsi, 2012, 1)

This interest on animal behavior research can be tracked in recent calls for ethologist to participate in HRI research teams and fora:

> This kind of design issues [appropriate appearance and behavior of robotic pets] can only be tackled from a multidisciplinary perspective, through methodological experimental explorations using the tools of anthropology, psychology ethology and sociology in addition to engineering methods. (F Kaplan, 2005)

As Ronald Arkin –one of the most outstanding researchers and divulgators on robotics such states:

> While much attention has been paid in robotics to neuroscientific models of behavior [...], less attention has been paid to realistic ethological models other than in simulated studies. It is our contention that ethology provides great insights into the design of practical robotic systems. (Arkin et al., 2001)

The contribution of ethology to social robotics developments are both substantial (e.g. the functional approach, the attachment behavior) and methodologic (e.g. systematic observation of social behavior in the wild) and can be summarized in three axes: i) deep understanding of *whys* and *hows* (i.e. functions and mechanisms) of our associations with non con-specific partners along humanity history ii) inspiration for animal-like robots' design and iii) methods to investigate HRI in naturalistic settings (i.e. behavioral and ecologic approach)

In this sense Miklósi (2012) postulates that ethologists might play a double key role in social robotics developments, to which we add a third one:

1. Inform robots' performance design, based on observed company animals' social behavior and human-animal dyads' behavior.
2. Provide well-proven scientific evaluation methods based on systematic observation of social behavior as it unfolds in context, rather than asking people about what they do.
3. Provide the functional perspective, distinguishing between investigating the reasons of a particular social behavior (e.g. communicate intent) and the mechanisms through which it is instantiated (e.g. facial expression). The basic assumption is that the better one can define the function –of a companion robot in this case- the more likely the appropriate mechanism is discovered (ethology) or implemented (engineering).

In fact, we can see that HRI community has turned its attention towards ethology methods and techniques to measure interactive behavior with social robots. The lack of agreement on research methods and the limitations of physical science models to study complex interactive behavior in natural environments (see Section 2.4. *Methodological issues in social HRI research*) make HRI researchers look at the tradition of ethology to measure human non-verbal behavior and non-human behavior (i.e. robots' behavior), from an *ecological* perspective.

As an instance of the growing mutual interests between HRI and ethology communities, we refer here to three outstanding research groups from the background of ethology, animal behavior and human-animal interaction that have recently contributed with new and insightful research to HRI:

– *Family-Dog Project*[1] gathers researchers from three institutions: the Eötvös Loránd University, Department of Ethology; MTA TTK Comparative Behavioral Research Group and MTA-ELTE Comparative Ethology Research Group. The head of the group

[1] http://familydogproject.elte.hu/wordpress/

is Prof. Ádám Miklósi and salient researchers Marta Gácsi (we can read on the group website "currently her major research interest is the application of dogs' interspecific social behaviors as a model for designing more "social" service robots[2]) Gabriella Lakatos and Tamás Faragó with a decisive contribution to the European funded project LIREC.

- *Center for Human-Animal Bond* (CHAB)[3] at the Purdue University College of Veterinary Medicine, Indiana, USA. The director is Alan M. Beck, leading a research program on *Pets and Robot Pets with Children and Older Adults*. Other outstanding researcher is Gail Melson leading a research line on *Children and emerging technologies*[4], from the development perspective.
- *Human Interaction with Nature and Technological Systems (HINTS) Lab*[5] with the Department of Psychology, University of Washington, USA. The director is Peter H. Kahn, Jr., psychologist, leading research programs on HRI like *HRI: Robot Pets* (Robotic Pets & Children; Robotic Pets & Elderly; Robotic Pets & Online Discussion) and *HRI: Humanoid Robots*[6].

The ethological approach suggests that human-robot interaction should be considered as a particular case of inter-specific interaction and that human-animal interaction can provide a insightful model for designing social robots better than the interpersonal models. The reasons that support this position are at least three: i) the technology is not already able to emulate effectively human social performance (so it's better to look for simpler behavior models) ii) human-likeness is not always the best presentation for a social robot according to its purpose iii) non-human like social robots generate lower expectations about their social smartness than human-like robots, what generally result in smoother interaction and more satisfactory experience.

It has to be noticed that this third reason on avoiding rising too high expectations on robot's social competence it is not independent from the other two - the current technological development and the role taken by the robot- but goes beyond it. Even if it was possible to emulate effectively human communication, we could prefer to propose interaction at the level of company animals expected behavior.

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[2] https://familydogproject.elte.hu/staff/
[3] https://www.vet.purdue.edu/chab/
[4] http://www.gailmelson.com/books---research.html
[5] (http://depts.washington.edu/hints/)
[6] https://depts.washington.edu/hints/projects.shtml

The three reasons would be elaborated here in more detail:

1. Lack of technological development to successfully mimic human social performance.
   It is unlikely that socially interactive robots will in the near future reach even the lower level of complexity that is characteristic for human-human companionship. Thus there is a need for an alternative model of companionship, in words of Maklosi, “robots should be anything but a human” (Miklósi, n.d.).

2. Necessity to adopt a functional approach to decide on the model of interaction (human-human vs. human-animal).
   There are some key questions that quickly arise from the functional perspective that surprisingly are often overlooked by HRI developers: Why do robots need to behave socially toward humans? (Miklósi & Gácsi, 2012); Do we really need human-likeness for companionship in the current application domains? Do we really need robots cohabitating with us in our homes?; Which is the value of a living with robot? (F Kaplan, 2005).

   > [...] the question has to be asked whether human-like communication is actually necessary—all the more if we do not plan to have relationships with robots that resemble the relationships to our partner or children. (Krämer et al., 2011)

   > [...] social robots should not mirror exactly human social behavior (facial expressions, language) but need to be able to produce believable social behaviors that provide a minimal set of actions by which human-companion cooperation can be achieved. (Kovács, Gácsi, Vincze, Korondi, & Miklósi, 2011)

   > Dogs, for instance, have several abilities that facilitate smooth interaction with humans: they are able to initiate communicative interactions, rely on visual human gestures, and recognize simple forms of visual (joint) attention. (Miklósi, 2009 in (Krämer, Eimler, von der Pütten, & Payr, 2011)

3. The necessity of adjust users’ expectations to the current robot’s competences

   Robot’s human-likeness is often a pitfall for smooth interaction. The high expectations aroused based on smart human-like affordances could dramatically be defeated in a few minutes interaction. The tolerant people show up to be with their technologic partners’, disappointment and arduous interaction can rapidly not only dissipate the initial enthusiasm but undermine irreparably its believability.

> It seems that animals inhabiting in human communities may provide a good model for a broad range of robotic companions. The fact that they have been present in our close environments through most of the modern human history argues for some general function but there have been some suggestions for particular functions as well (Miklósi & Gácsi, 2012).

On the other hand, some authors consider that the dog-human models do not contribute either to make interaction with robots smoother provided dogs have themselves social skills that cannot be implemented in robots yet. However, maybe the great difference between trying to *socialize* with a pet-like robot or with a human-like one is not really that pet social behavior is easier to mimic artificially–that probably is- but that our expectations are lower (Krämer et al., 2011).

> It is our guess that because people do not expect full social responsiveness from animals, children (and adults) will find human-pet/robot relationships more satisfying that human-humanoid relationships, at least until the robotic technology is able to mimic more successfully human behavior. (Kahn, Jr. et al., 2006, 432)

Thus, the discussion could be transferred from the engineering-oriented question *Is current technology capable to emulate the natural way people interact with people*? into: *Should social robots emulate people communication and interactive behavior*? Changing the focus from the *can we* question to the *should we* debate, unavoidably open the perspective and shine the spotlight on values and ethical issues.

Dog-Inspired Social Interaction

We agree with Miklósi that dogs are very good models for robotics being the best representatives of pets, with the most successful adaptation, sharing the family close environment in human communities and taking part in complex social interactions and lasting relationships (Miklósi, n.d.).

Dogs proved to be an especially promising biological model since have managed evolutionary during the domestication process *to be allowed* to live closely with human and would probably provide inspiration to design useful behaviors for other creatures –robots- attempting to socialize with us in a long-term basis within our homes.

Furthermore, not only dogs are adapted to human but probably we humans have also get used to dogs and through ages of human-dog association we have learned as well to interact smoothly with them in a cycle of mutual adaptation. The hypothesis is that dogs' social behavior is particularly readably for humans and interacting with them is easier and more intuitive than interacting with other domesticated species.

Recent studies (Koay et al., 2013; Kovács et al., 2011) demonstrate that applying human-dog interaction as a model for designing robots' behavior towards the users would result in readable, believable and socially acceptable human-robot interactions in case of different robot embodiments. In addition, the dog-inspired social behavior proved to be a suitable medium for making people attribute intentions and emotional states to non-humanoid robots (Lakatos, 2014).

Human-animal interaction provides a rich source of knowledge about the key skills and mechanisms to interact effectively with humans under a wide range of conditions. For instance, dogs are very good at showing social interest in what is going on, deploying look at behavior (eye contact, face), following around people. Interestingly, this kind of behavior could be displayed by a robot to make themselves to be accepted as living-with entities. Other dog behaviors to be used as inspiration could be greeting and leading behavior (Miklósi, n.d.).

> To reveal the basic behavioral primitives necessary for successful long term social relationships it seems beneficial to investigate natural social systems in which humans interact with non-humans. We suggest that observing specific aspects of human-dog interaction may offer insights for making improvements in present day social robotics (Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014)

The smart and intuitive it seems the pertinence of dog-owner model to inform HRI developments in companion robots, this perspective raises a lively controversy in the HRI community. The dog-inspired approach has been discussed recently in depth and collected in an special issue of the Interaction Studies Journal (15:2 2014) that compiles the critical review of up to seven outstanding researchers on HRI from different domains (computer science, ethology, design) who expose their critical views on the work of Faragó *Social Behaviors in dog-owner interactions can serve as a model for designing social robots* (Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014).

In this paper Faragó proposes the dog-owner model as one of the more fruitful and insightful ways to map social robots behavior, studying the interactions between family dogs and their owners that reveals low level social behaviors that can enrich the behavioral repertoire of social robots. The basic hypothesis is that social robots would be more acceptable and believable to humans if their behavior is modelled on the basis of functional analogs of human-dog interactions. From the experimental data obtained from the study of 29 dog-owner dyads, they affirmed that there are two kind of dog-owner social behavior: individual dependent (e.g. proximity seeking, tail wagging) and context specific (e.g. orientation, exploration and activity). From these findings, Faragó conclude guidelines for social-robot behavior design.

In Table 2-2, we summarize the arguments of the seven authors contributing with their critical views about the advantages and limitations of Faragó's works organizing their backgrounds and main contributions under the following labels: *Overview, Functional, Role, Expectancies/Other* and *Ethics*.

Table 2-2 Overview of critical reviews of Faragó's work (2014)

	Background	Overall	Functionality	Role	Expectancies/Other	Ethics
David J. Feil-Seifer, 2014	HRI researcher on Social Assistive Robotics, humanoids in therapy-related interventions for children with ASD (Bandit) Computer science and Engineering	Critical/skeptical position There are several instances where dog behaviors are not appropriate or even detrimental for the goals of the robot	- Dog-like behavior is only appropriate for dog-like robots that perform only as companions as a primary goal - If seen as an appliance social identity is not necessary to adoption even in the home	According to the role it would be suitable or not (ex. coach/companion)	If you consider humanoid robots a pet-like interaction would detract from a user's experience with the robot.	
Marti, 2014	Philosophy, Design and Computing Industrial Design TU/Eindhoven		There are 3 kinds of mimicry: Surface, behavioral (the focus of Faragó) and functional.		- Resemblance between robots and animals creates greats expectancies. A suggestion is that robots show their "being imperfect" through design - The problems with behavioral mimicry is that if you only mimic one behavior can deceit people that infer that other behaviors would be as well performed.	

	Background	Overall	Functionality	Role	Expectancies/Other	Ethics
Matellán & Fernández, 2014	Computer Science and Robotics	The interaction with a domestic dog is just ONE of the sources of inspiration for social robots' design. Long-term studies (experiments) with social robots are required. The goal is not to recreate the internal operations, but the external functionality, that is to simulate the mechanisms that make humans perceive their pets as social partners.	The paper does not distinguish between "different levels of interaction" required by the different function social robots are supposed to fulfil. The robot should be autonomous without the need to have specific mission assigned to it.	Domestic dogs do not need to have a specific mission assigned to them at home; their only mission consists of interacting with their owners because they are pets. Pet's additional task is to maintain and increase their relationship with their owners.		- Ethical concerns may emerge when creating social robots that could be perceived by humans as Pets. - Do robots deserve some recognition of rights provided they feature personality?
Melson, 2014	Developmental Psychology, Educational Psychology, Behavioral Science Human-Animal Interaction Research interest: the significance of animals, nature, and robotic pet technology for children's development.	Robots' designers will benefit greatly from this study. The paper discuss in depth the 2 behavior studied in Faragó's: *Social monitoring* and *Reunion/greeting* after separation BUT do not underline the differences between living dyad interactive behavior and the hybrid dyad's.	- It is not clear that individuals want their interactions with a social robot to more and more closely imitate the human analogue (a certain degree of ROBOTNESS may be preferred). - Maybe robots have epistemological standing as a particular kind of being. - Living dyads as dog-people is a dynamically changing and mutually adapting system that it's extremely difficult to generalize to human-robot social systems.		The most closely approximate their living analogues, more room for deception and subrogation what seems not to be desirable.	

	Background	Overall	Functionality	Role	Expectancies/Other	Ethics
Nicolescu, 2014	Computer Science	Depending on the type of target application, dog-like behaviors may or may not be best suited for robot-human interaction. In the domain of dog-owner interactions the aspect of joint attention can potentially be studied to map to robots.	It would be very interesting to extend the studies to the interactions with service dogs e.g. assisting the disabled, rescue, personal protection, or sled dogs, because due to the nature of their roles, these animals engage in much richer interactions with their owners and could provide an even better basis for developing behavior for interactive robotic systems.	Robots can interact with people in multiple roles e.g. service robots, tutors, peer collaborators, healthcare assistants, toys, artificial pets, or companions for the elderly (Fong et al 2003).	Proximity is one of the behavioral parameter analyzed by the study. It could be interesting to add the knowledge about application of Proxemics in HRI One finding in Proxemics in HRI is that dog owners behave differently about the social use of space.	
Fischer, 2014	Design and communication, applied to HCI and HRI	- Naturally occurring interactions even with service work are not studied. - The study fails to show whether people really liked their dogs' behavior or whether they just accept it. - The study ignores interpersonal variation, personal preferences - It provides no means to account for human-dog/human-robot interactional adjustment	- People do not simply transfer from human interaction to interaction with robots but adjust behavior during interaction according for instance to the feedback provided by the robot (e.g. gaze). - Empirical studies demonstrating that contingent social robot response is a determining factor of HRI provide the detail to reliably inform robot design regarding which aspects of interactions are crucial for the perceived quality of human-robot interaction.	People interact differently with robots exhibiting different functionalities since people's expectations about robot capabilities shape their behavior toward the robot as well as their evaluations of it.	Robots play different roles and meet different needs in human households compared to dogs so people will initiate different kinds of interactions, hold different expectations and exhibit different kinds of behaviors in interactions with robots.	-

	Background	Overall	Functionality	Role	Expectancies/Other	Ethics
Dahl, 2014	Artificial Intelligence and Knowledge Engineering	It's insightful but application to HRI face challenges due to the wide range of potential users and domains. A dog-owner model of interaction is inappropriate for many of the roles robots are expected to undertake Dogs are not universally understood or appreciated.	The model emphasize on monitoring and dependency may present problems as well as advantages (e.g. intrusion that could be tolerable in a dog provided their **needs** but perhaps not in a robot) 1. Look for other behavior to achieve the same levels of functionality (e.g. use passive non-intrusive behavior to achieve monitoring) 2. Dependence may present a danger of rejection through excessive imposition	Different roles define different social relationships between a robot and its users in terms of e.g. dominance, authority, initiative and expertise, that requires different interaction behaviors (appropriateness depending further in individual and cultural contexts)		Treating robots as subservients could lead to: i) a decrease of respect in treating robots and ii) treating as subservients humans that take similar roles. It's necessary to graduate the level of dependency according to the duration of the relationship for reducing the emotional impact of separations for instance in hospitalized interventions.

2.1.3.3. The Role-Centered Approach and the Theory of Mind

As mentioned in the previous section, HRI community faces a dilemma: should human-companion interaction be built on basic principles of human-human interaction or, on the contrary, on human-animal interaction? The major advantage of applying the interpersonal paradigm seems to be that humans will not have to adapt when communicating with robots and the main drawback is that the crucial abilities required cannot (easily) be implemented (yet).

We will propose a third way to approach this question as a false dilemma, thus the question can be reformulated in terms of figuring out whether human-like communication is actually *necessary*:

> Alternatively, we can ask whether it would be sufficient to provide an artificial entity with the communicative abilities of, for example, a dog […] or develop a radically new and innovative form to model communication between humans and artifacts- one that draws neither on human-human communication nor on human-animal communication. (Krämer et al., 2011)

Instead of investigating how much human-likeness is required to effective social human robot interaction (Sciutti A. & Sandini G., 2014) maybe the focus might to be put on first defining robot's function in a particular scenario. In the case of a social robot, function derives mainly from the role the robot is supposed to play (see Fig. 2-1).

> One such basic requirement is the agreement of certain tasks with certain basic types of appearance; for example, a high degree of human-likeness for tasks that are high on social interaction (for example, care giving, teaching). In contrast, companion, pet, toy, and entertainment applications do not imply a necessity for human-like appearance, but rather animal-like appearances are preferred. (Lohse, 2010, 50)

Therefore the matching between role demands and robot competences is a crucial criterion for believable an effective social robots design (Dahl, 2014, 190; Díaz et al., 2011; Diaz, Nuno, Saez-Pons, Pardo, & Angulo, 2011; Feil-Seifer, 2014). To achieve this optimal matching is necessary to design and assess HRI in terms of role consistency (Kerstin Dautenhahn, 2003; Díaz et al., 2011).

Finally, what is at stake selecting the more intuitive model to design social robot's performance is how easy and natural it would be for users to build a particular representation of the communicational frame, attributing the social agent the *correct* mental states, such as intentions and beliefs that can facilitate the *mindreading* of others' knowledge, intentions in actions (von Scheve, 2014, 70). The more consistent the robot's appearance with its performance, and both with the robot's role the easier the understanding of the interactional space. Getting to know how to interact with a particular robot is a demanding socio-cognitive process of making sense and re-evaluating expectancies. One very insightful approach to the dynamics of human-robot communication is the Theory of Mind (ToM). Most remarkably, both psychologists (Astington & Jenkins, 1995) and roboticists –and in general experts in AI- (Kerstin Dautenhahn, 2003; Krämer et al., 2011) drawn on the theories of mutual understanding to explain how human and robot may acquire the ability to represent each other's mind. Psychologists (from social and development disciplines) and roboticists deal with the same question: how can an agent (child or robot) acquire enough knowledge about their social partner (a child or a robot) to communicate and interact smoothly, satisfactory and effectively.

In intraspecific communities the mechanisms to build such a representation of other's knowledge, beliefs, desires and intents, highlight the social immersion and the richness of communication and the quality of the relationships with other conspecifics: parents, care-givers, peers, other adults, from the very initial phases of development. Immersion in a social environment of con-specifics and the projections –imputation- of our own mind in others –not so different of myself- seems to provide the foundation of the developmental acquisition of a compliant ToM.

But which are the mechanisms to represent other's mind when confronted with a non-conspefic partner? Do children acquire a ToM of their family animals? It seems clear that they do. One of the reported children's beneficial effects of bonding with companion animals is the development of ToM abilities when interacting with their pets, the "discrepant others" (Myers, 2007) from which they feel different but emotionally related (Melson & Fine, 2010, 181). And what about communicating with artificial buddies? How could children make a useful representation of the world of this artificial minded creatures that appeal them to be interacted socially?

Perspective taking –understanding the feelings, thoughts and motivations of others- and common ground -the sum of the mutual, common, or joint knowledge, beliefs, and suppositions- are the key mechanisms to adjust communication and joint action (Clark 1992 cited in Krämer et al., 2011). Robot's appearance, affordances and behavior are the cues on which children form their understanding of the robot's mind. For instance, in the interactive frame of playing with a pet robot, noticeable feedback indicating that a meaningful goal has been achieved (e.g. an ostensible sound of chewing and content when been fed by the child) helps to form the shared belief of a successful joint action.

Forming a useful ToM to interact smoothly and successfully with a robotic counterpart implies shaping and refining the other's mind working model on an ongoing basis in accordance with differentiating knowledge acquired through experience. Provided that in the current state of technology is the human partner who has to adapt to the robot, the point is how to design initial interactions to make the adaptation not only less effortful and frustrating but challenging and enjoyable. That is to say, to turn this effort into one of the main self-rewarding process of engagement

2.2. Bonding for Companionship

One primary goal of current robotics research is to develop companion robots able to engage the user in a long-term relationship to deliver services in close proximity, such as health care and domestic assistance (e.g. helping elderly people in their homes).

It is hoped that robots that possess a range of sophisticated social abilities may be regarded as companions. However, a not minor question arises: there is no evidence based knowledge about what makes an agent an acceptable companion. One promising way to face this challenge is to find a good model for *companionship* on which the robotic design could be based (Maklosi LIREC, 2008).

A great body of research in robotics concentrates on the question of how to design a robot that engages people beyond the initial phase of novel human-robot interaction experiences. In this context, the development and implementation of humanlike abilities in robots like theory of mind, emotion and empathy are required.

> Although it is interesting to know how the implementation of different abilities influence the perception and evaluation of robots it is also for great importance, albeit largely neglected, whether and how people emotionally bond with artificial entities. (Rosenthal-von der Pütten, y otros, 2014).

> The key feature or smallest common denominator of artificial companions is that they are sociable in some way, i.e. they have the potential to form social relationships with their human users or owners" ... "to realize this sociability potential, artificial companions are supposed to be able to interact and communicate verbally or non-verbally with humans and 'understand' or even "befriend" them, ideally in a *human-like way* (von Scheve, 2014).

Artificial companions should have some kind of 'personality' or be 'personality rich', have motivational concerns, be proactive, and –very generally- be believable and consistent in their behavior. Last but not least, sociability is usually seen as involving the capacity for emotionality and in particular to form emotional bonds with users. Emotionality here involves two basic capabilities. First, artificial companions should exhibit emotional behavior and read emotionally users' actions. This includes expressing certain emotional states verbally or non-verbally, as facial expressions or gestures, or initiating behavior based on some emotional state, for example withdrawing in cases of fear or approaching and exploring in cases of joy and happiness. Second, artificial companions should be capable of "detecting and reacting to the emotions of their users in appropriate, socially acceptable ways" (von Scheve, 2014).

2.2.1. Functional Approach to Companion Robots

Function

As we have mentioned, the optimal social behavior of the companion robot depends on its expected function. Although there have been only a few attempts to define the functions of companion robots, it seems inescapable to come up with a functional definition of a companion before such agents are constructed (Miklósi & Gácsi, 2012)

> ... companionship covers a broad range of social relationships then it may be useful to regard all social robots as companions with the level or complexity of the social behavior depending on the function of that companion. (Miklósi & Gácsi, 2012)

Thus, before designing the mechanisms it is unavoidable to define the purpose adopting "a more fruitful perspective focusing the potential value of a robot for its user, investigating our expectancies towards robots to understand the kind of experiences that would make a robot valuable as every day object" (F Kaplan, 2005). One should define clearly the function or "uses" of the robot and also specify quantitative (we would prefer measurable) benchmarks that are useful in revealing whether or to which extend the expected function has been achieved (Kahn, Jr. et al., 2006; Miklósi & Gácsi, 2012).

Therefore, finally the crux of the matrix is to figure out what is the function of a companion robot.

> What is the goal of an engineer that has to design an artificial friend? This question is rarely asked. (F Kaplan, 2001)

Although it seems to be an inclination in the social robotic field to make equivalence between social robots and companion robots, from our perspective is important to distinguish between a socially interactive robot and a companion robot. The former, emphasizes specific behavioral skills of a robot (see Section *2.1.2. Social robots*) that enable it to interact with humans under some specific conditions –mechanisms-. On the other hand, a companion robots refers to a functional category, companionship, certainly not easy to define, that encompasses from just enjoying each other's' company, workmates, people who meet occasionally to have lunch, and close friends (Á. Miklósi & Gácsi, 2012, 2).

From this point of view, the function of a companion (robot) would be defined as the effect on the partner in terms of a generic feeling to belong, to matter someone; a sense of affinity and affiliation, experiencing warmth, closeness, union and intimacy. A companion alleviates the feelings of loneliness and makes one feel accompanied and supported. Companionship is the experience of liking and being liked.

Even though the delimitation of affiliation and relationship is elusive both in the ethological and in the psychological literature, it is also clear that there is both a qualitative and quantitative difference among different types of social relationships, ranging from incidental social interaction (even if it is regular), to a close friendship. We may describe companionship as step toward friendship which is based on repeated social interaction between biologically unrelated partners i) who provide mutual support, ii) whose interactions stretches over long time, iii) who does not expect any investment to be returned immediately, iv) who acquire, maintain and actively update knowledge about each other, v) who show an increasingly complex tendency in their social interactions.

Therefore, the key concept seems to be closeness in several meanings: physical closeness (proximity, assiduity, go along with, join in action, being frequently in the company of) and psychological closeness (reciprocity in liking and being liked, intimacy, trust, affinity, union of interests and feelings, empathy, emotional adjustment, understanding) (Kelley et al., 1983).

Reflecting about social robots and how could be mapped on them the essence of companionship, Jacobsson (Jacobsson, n.d.) highlights the feature of *assiduity*. A companion is *someone* that stands by you -both literally and figurative- that stays around in close proximity to you not only physically but psychologically– and that makes you feel that you are not alone. According to Jacobsson, in terms of behavior a companion is plainly "someone that follows you around and spends time with you" –displaying closeness, proximity and assiduity-. To study companionship with robots is to study what people really want to do with the robots, how do they spend time on robots, what they do together with this sort of agent, that is more like something you interact with or something you have with you all the time, like a cell-phone (Jacobsson, n.d.).

Carsten Zoll affirms that human-companion robot relationships resemble human-human relationship as both are grounded on psychological and physical intimacy. The development of a relationship is grounded on trust and control –of the interaction and on the data- that come through satisfactory and successful interaction: put together people with companion robots and the robot must demonstrate that it is trustworthy (Zoll, n.d.).

Mechanisms

On the other hand, this function of companionship has to be deployed through interactive behavior –mechanisms- according to the role assumed in a particular situation –butler, friend, pet- and the robot's particular embodiment. While in nature, evolution ensures relatively close correspondence between function and mechanisms, that is the function will constrain the mechanisms, in social robotics this evolutionary concept is often referred to as believability which in practical sense means that a robot should act in line with the expectancies invited by it, or alternatively, it should not give the impression of having higher capacities than it has in reality (Miklósi & Gácsi, 2012).

> Researchers and engineers use a wide range of mechanisms for supporting assumed functions of companion robots; these mechanisms involve two broad categories: embodiment and behavior. The former is often utilized in order to evoke some primary social responses from the human, the later supports a flexible, proactive and reactive interaction between the robot and the human. (Miklósi & Gácsi, 2012)

> At the moment there seem to be no design rules for companion robots, researchers using a mixture of mechanisms that is at their disposal, ranging from relatively realistic copies to virtual, fictitious agents. (Á. Miklósi & Gácsi, 2012,5)

The pertinent level of complexity of the social behavior depends on the one hand on the performance expected from the robot's role along with its communication resources (i.e embodiment and intelligence). For instance, a robot in a hospital can be a cleaning assistant, a helper to displace patients to different units, a receptionist in a front desk (Kerstin Dautenhahn, 2007b; Miklósi & Gácsi, 2012) or a facilitator in a educative programme in the pediatric ward (Ros et al., 2016) .

Moreover, the robot's competence depends on robot's embodiment and *intelligence* –perceptual, motor, cognitive and communicative capabilities-, that varies dramatically from one platform to another, even if we only consider the robotic-pets subclass. Assisting, walking along with, joining in action, approaching smoothly, attending requests seem to derive naturally from the concept of companionship but only few social robots could be capable to provide this type of expressions of support and friendship. Robotic pet are not able to provide services of the kind, actually. However *useless* robots (Frédéric Kaplan, 2005) can still keep company and offer warmness. Actually, the essence of companionship is not the utilitarian contribution to partner’s wellbeing other than the positive affiliative disposition towards him/her.

2.2.2. Concept of Bonding

> Of interest in the context of artificial companionship is the type of bond between human beings and robotic artefacts that is not merely situation-specific but rather cross-situational and that robotics researchers (and not only they) like to term a ‘social relationship’. (Pfadenhauer, 2013)

Tentatively we understand social bonding as a type of attachment or positive association that is present or define rewarding affiliations like friendship and that are related to the human need to belong. Bonding is the socio-psychological process of stablishing affective links with social partners -inside and outside the family environment- and conforms different relationships as filiation, friendship or erotic partnership, that serve key functions in our communities as reproduction, breeding and cooperation.

In its wider sense we consider bond forming, social bonding or just bonding as a type of affiliation that includes but is not limited to attachment in its restricted meaning as the primary bond that infants stablish with a main care-giver that facilitates the provision of basic needs of nurture, protection and company (Ainsworth, Blehar, Waters, & Wall, 1978). In a broader sense bonding encompasses as well other affiliative relationships that infants, youngers and adults stablish over time between peers – comradeship, friendship-; romantic and erotic relationship and associating with companion animals, being this late an interspecific relationship.

In the particular case of relatedness with social robots or more generally with personified technologies or artificial agents –including digital characters- this affective bond can emerge in different kinds of relationship. In symmetric relationships the power and control are evenly shared (e.g. a robotic playmate in a board game) while in asymmetric interdependent roles the robot can take the one-up position (i.e. the role with more power/influence such as coach, nurse, teacher) or the one-down (e.g. assistant, butler, pet). The definition of the interdependent roles adopted by child and robot will depend on the perceived social situation and the features, competencies and functions supported by or attributed to the robotic platform.

As seen in the previous section, *companion* robots have been designed to engage people in social rapport and to induce people to stablish a close connection or even intimacy with them over time beyond the specific encounters with the robot.

The key features of this emotional bond with companion agents are the intersubjectivity (i.e. attribution of social partnership or agency), the positive affect (closeness, warmth, friendliness)

(Kelley et al., 1983), the concern about other's wellbeing, the preponderant role of the emotional reward over the instrumental (i.e. comfort, enjoyment, entertainment, company, mitigation of loneliness), and that orient to satisfy others' needs in a communal rather interchange (utilitarian) associations (Krämer, Eimler, von der Pütten, & Payr, 2011, p. 492) .

Bonding is the essence of companionship and express through particular cognitions and perceptions, observable behavior (e.g. proximity searching, behavioral alignment) and through the subjective experience such as willingness to be close, sorrow for separation, missing the robot when absent, enjoying interaction, emotional contagion (Krämer et al., 2011).

Kahn in this study based on the content analysis of 6.438 Internet discussion forum postings by 182 puppy robot AIBO owners (see Fib. 3-1 b), reported that fifty-nine percent of adults spoke of having established a social rapport with the robotic pet, including communication, emotional connection, and companionship (Melson, Kahn, Beck, & Friedman, 2009).

Therefore, there are two axes to identify and evaluate bonding: the engagement and the social rapport. Engagement is observable –e.g. time spent with, joint activity, attention, search of proximity, absorption- while the emotional involvement has to be self-reported and/or inferred more interpretatively from behavior.

None of the two dimensions of bonding –engagement and the subjective experience of closeness- can independently cover the complexity of the concept. While a child can be absorbed interacting with a robot for hours if the interest comes from a technological curiosity we cannot say that a bond is established unless we can identify as well emotional involvement with the agent.

The pseudo emotional bond that the robot may develop with humans or other robots is beyond the scope of the present work, even though there are interesting studies that investigate this emotional behavior in order to design robots able to bond affectively to people introducing emotions and affects in the learning and decision making processes emulating the affective-cognitive process in humans (Moussa & Magnenat-Thalmann, 2013).

2.2.3. Models

From our perspective bonding has to be understood and addressed as a developmental dynamic process. The bond with robotic pets expresses through emotions, judgements, interactive behavior and attributions that change according to the phases of development, being different between preschoolers, children, teenagers and adults. As a manifestation of other socio-cognitive changes involving mainly reasoning (e.g. the categorization of entities into ontologies) and interactive behavior perceptions towards and interaction with robots evolves along with children development (Kahn, Jr. et al., 2006; Pitsch & Koch, 2010)

From this perspective, Pitsch (Pitsch & Koch, 2010) points out that the perceptions of children on a robotic pet is a process that emerges step by step during and from the interaction with the system, from the first contact situations. Without any claim for generalization the author identified the following stages in a preliminary study based on the observation of children playing with the pet-robot Pleo (see Fig. 3-1 a):

1. First intuitive approach, handling an inanimate object
2. Socialization into appropriate treatment of Pleo experiencing the robot as an animate object.
3. Exploring and experimenting Pleo, developing interactional patterns.
4. Experiencing the robot as a polyfunctional object with which is possible to interact in different (real or symbolic) worlds.

These data suggest that a different approach –questionnaires and interviews diverge from observational interactive behavioral data- should be used to capture the *real* perceptions and the process of building up categorizations on the systems and its *dynamics* and *evolution*.

Based on Levinger's model (Kelley et al., 1983; Levinger, 1980) long-term relationship evolve through five phases that have been adapted to inspire long-term HRI categorization (Barco Martelo, 2017):

1. Attraction Stage: children's initial attraction caused by the novelty effect of having a new interactive mate.
2. Building Stage: children engage with the robot companion in self-disclosure and become increasingly interdependent.
3. Continuation Stage: children show affection to the robot to enhance the relationship (e.g. putting a name to the robot, referring to the team as we).
4. Deterioration Stage: interest decline because there is an imbalance between the efforts from children versus the rewards from the robot.
5. End Stage: children stop using the robot and show no interest to play with it again.

Kramer proposes a three level model for robot social relationship, as three layers or dimensions rather than phases: (Krämer et al., 2011; Rosenthal-von der Pütten, A. M., & Krämer, 2014).

1. Micro-level: specific *communicative acts* in isolated encounters (engage in interaction)
2. Meso-level: models for relationship building based on the human drive of the need to belong (engage in relationship). At this level of analyses, the aim is describing the prerequisites for the establishment and maintenance of relationships and the basic dimensions of human relationship (communal vs. utilitarian relationship).
3. Macro-level: the roles that can be helpful frames when trying to shape human-artifact interaction.

2.3. Robotic Pets

2.3.1. Nature

In recent years there has been a movement to create robotic pets, a small subclass of companion robots which embody interactive and adaptive computing technology in forms that mimic aspects of their biological counterparts as dogs or cats, both in appearance and behavior (Kahn, Jr. et al., 2006; Miklósi & Gácsi, 2012). They are robots to be regarded as artificial life forms, as another expression of sophisticated emulation of the natural world allowed by technological advances in interactive computing (Melson, Kahn, Beck, Friedman, et al., 2009, 546).

> Robotic "pets" are being marketed as social companions and are used in the emerging field of robot-assisted activities, including robot-assisted therapy especially for vulnerable populations. However, the limits to and potential of robotic analogues of living animals as social and therapeutic partners remain unclear. (Melson, Kahn, Beck, Friedman, et al., 2009, 545

> Robots because they are autonomous, situated and physical artifacts tend to spontaneously foster interaction patterns that are usually characteristic of our experience with living animals. (F Kaplan, 2005, 62)

There has always been some connection between robot building and our experiences with animals. (Á. Miklósi & Gácsi, 2012, 3).

A robotic toy is an interactive robot designed for basic leisure activities such as play, creativity, playful learning and entertainment that have a software component, which distinguishes them from other mechanical or low-tech artefacts. Moreover, been marketed for personal use among children unlike a piece of software that is installed on a computer or a mobile phone, a robot is an active tangible artefact that interacts directly with the world around.

Robotic pets –different from other family or domestic robots- are designed to be *useless* in the sense that they do not perform any tasks or services for users, such as the dog AIBO, the baby dinosaur Pleo -both of them are claimed to develop a *personality* and acquire new behaviors with time- and the baby seal Paro. On the other hand, other robotic pets such as the Teddy Bear Huggable are designed to interact with people in primarily therapeutic –they can be considered Social Assistive Robots- or educational settings (Fernaeus et al., 2010)

Assuming the well-supported *basophilic hypothesis* (Kellert & Wilson, 1993) –humans' natural predisposition to affiliate with life -, the fundamental questions to psychologists and designers are what specific features of life forms focus human attention, stimulate interaction and activity, provide companionship, provide cognitive enrichment, and establish conditions to accord an entity moral regard.

> Animals appear to be optimally discrepant others by the time of early childhood, offering just the right amount of similarity to and difference from the human pattern and other animal patterns to engage the child. Crucially, animals are social others… because they display the hallmarks of being truly subjective others. Thus pets can become a source of companionship and support for children. (Myers, 1998 p10 in Kahn, Jr. et al., 2006, 407)

Following Myars, we can go further and state that pet-robots features a *double otherness* respect human: different nature - artificial vs biological entities - and different species in their analogy of life -human beings vs (other) animals (e.g. seals, dogs, cats, dinosaurs, elephants). What is to be demonstrated is whether –and how- this double otherness is a hurdle or an opportunity for gratifying, smooth and useful cohabitation.

2.3.2. Children and Robotic Pets

Specificity of Children-Robot Interaction

Not surprisingly children-robot interaction (CRI) seems to be fundamentally different from adult-robot interaction, children showing a more positive attitude and engaging more easily and smoothly in interaction with robots than adults. CRI is a very salient topic in current HRI research for informing educative and therapeutic applications, maybe the more promising and relevant field in social robotics developments for children.

> Children, for reasons not fully understood, respond much more readily and strongly to social robots. As such, human-robot engagement is significantly more easily attained with younger children than it is with adolescent or adult users. (Ros, Nalin, et al., 2011)

Children interacting with robotic pets seem to be attired simultaneously by the attraction of a smart interactive toy and for the similarity of their beloved animal buddies. Pet robotics merge gracefully the appealing and wonder of smart electronic devices with the fascination that pets exert on children. We consider that both essences –astonishing performance and animal-likeness- reinforce each other: the wonder for the smartness and interactivity applied to one of the most valuable entities on children lives: their pets. Robotic pets are amazing for children because they are pets being robots and they are objects been life analogues. This excitement by the double nature of pet-robots maybe the main reason for their success among children challenging their cognitions about animate and inanimate worlds in different ways according to the different development stages.

Belpaeme states that HRI community has "discovered that human-´robot interaction works particularly well with younger users" and refers to the propensity of children to attribute life-like characteristics and eagerly maintain this *illusion of life* during interactions and their propensity to pretend play.

> Children typically do not see a robot as a mechatronic device running a computer program, but attribute characteristics to the robot which are typically expected to be attributed to living systems. This has been observed in both adults and children and that anthropomorphization is already strong at the age of 3 and possible at even younger ages. Furthermore, it would seem that children anthropomorphize more than adults do; or at least are more eager to maintain the illusion that the robot has life-like characteristics. (Belpaeme et al., 2013, 452)

Children tend to naturally engage in playful interaction with robots to which they attribute biological essences like desires and intents.

> Pretend play and anthropomorphism seem relevant to the ability of children to engage with robots and treat them as life-like agents [...] This propensity for social play spills over into technology: toys and specifically robots are readily treated as being alive and having "beliefs, desires and intentions". (Belpaeme et al., 2013, 452-453)

In addition to the increasing number of studies and contributions, a clear demonstration of the growing interest in child-robot interaction is the constant presence of this topic in the most relevant research fora in HRI (i.e. workshops on Evaluating Child Robot Interaction at the International Conference on Social Robotics 2015[7] and at the AM/IEE International Conference on HRI2016[8] and 2017[9]; and the workshop on Long-term Child-robot Interaction at the IEEE Ro-Man 2016[10]. We consider that CRI is already considered *de facto* a sub-field in HRI.

Developmental Cognitions, Emotions and Behavior towards Robotic-Pets

To better understand the potential and limits of robotic analogues of living animals as social and therapeutic partners, Melson (Melson, Kahn, Beck, & Friedman, 2009) carried out three studies that comprise i) observations of and interviews with 80 preschoolers, aged 3–5 years, during a 40-minute play period with AIBO and a stuffed dog (Kahn, Friedman, Perez-Granados, & Freier, 2006) ii) observations of and interviews with 72 school-age children, aged 7–15 years, who played with AIBO and a unfamiliar, friendly living dog (Melson et al., 2009); and iii) a content analysis of 6,438 Internet discussion forum postings by 182 AIBO owners, all presumably adults (Friedman, Kahn,&Hagman, 2003).

In the developmental studies, they investigated whether young children accord to robotic pet some measure of a) animacy or other properties or processes, b) emotions, desires or intentions, c) friendship and companionship and d) moral standing.

Overall, the studies revealed that

1. *Hybrid* cognitions and behaviors towards AIBO emerged: the robotic dog was treated as a technological artifact that also embodied attributes of living animals, such as having mental states, being a social other, and having moral standing (although this latter finding remained difficult to interpret).
2. Children's and teenagers' conceptualization and interaction with pet robots, demonstrated that children's reasoning about pet robots and their behavioral interaction with these systems differ.

From this findings, Kahn postulates that:

> In infants, robotic pets seem to blur foundational ontological categories, such as animate vs. inanimate. (Kahn, Jr. et al., 2006; Pitsch & Koch, 2010)

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[7] https://childrobotinteraction.org/participants/
[8] http://humanrobotinteraction.org/2016/authors/tutorialsworkshops/evaluating-child-robot-interaction/
[9] https://childrobotinteraction.org/
[10] http://web.media.mit.edu/~haewon/Roman-LTCRI/

From experimental studies on toddlers' interactions with robots, Meltzoff investigated the *agentivity* or agency attribution to robots and concluded that children regarded robots –a 50 cm tall humanoid mechanic-looking robot- as psychological agents –a *perceiver*, an agent that can see the external world- because children exposed to the robot interacting with another agent follows the gaze (its line of regard). Robots observed communicative and contingent mimic interaction elicits in babies the *agentive illusion* that the robot could see. The robots' capacity for generative imitation is a powerful cue to psychological agency and communication for infants. Imitation acts as an specially salient cue to psychological agency in human infants (Meltzoff, Brooks, Shon, & Rao, 2010).

In the same direction, Pitsch (Pitsch & Koch, 2010) bases her model on the cognitive dimension on interaction inferred from the behavioral analyses at the *interactional surface*. How the user perception, categorization and re-interpretation of a robot system emerges step by step during and from the interaction with the system, and how the user's attempts to establish coordinated *sequences of action* play a central role in this approach. From their studies –unfortunately not complemented by further research, as long as we know- they observed children in a particular time in the flow of interaction treat the robot as a polyfunctional object with which they can interact in *different world*s, real and symbolic ones and depending on the concrete ways in which she momentarily defines and redefines the situation, endowing the robotic pet with different qualities and properties.

> However, the use of available robot as an inanimate object, continue to be emotionally closely and intellectually involved in the experience. In this respect, agentivity does not seem to be a key factor in assuring a pleasurable and intriguing interaction experience. (Giusti & Marti, 2006)

From our perspective, the children's ability to attribute the robot biological essences at the same time that they *know* they belong to the inanimate world -what is not perceived as an insurmountable logical issue at certain development stages- is one of the key factors of the attraction exert on children. From our experience, one question children pose frequently referring to Pleo is A*re they real?* maybe a wiser proxy of the subjacent question *Are they alive?* that is incomparably easier to be answered by an adult.

Playing with a Robotic Pet

What we can see from the systematic studies on children conceptualization and interactive behavior is that these new types of robotic products have become something different than the purchased consumer electronics product. Users, thus, manage to create bridges in the interaction by staging, performing and also playing along with the unfolding experience, a practice that is sometimes referred to as *performed belief* within the field of pervasive gaming (Jacobsson, 2009).

One explanation to children interaction with pet-robots maybe the human tendency to project feelings and attributes onto objects through pretense or metaphor. Alternately, people may develop relationships with robotic animals in a process similar to the willing suspension of disbelief, the state we enter as we immerse ourselves in an absorbing novel, play, or movie. Another possibility is that a new technological genre is emerging that will increasingly challenge our existing cognitive categories, between for example alive or not alive, animate or inanimate, agentive or not, social or not. Indeed, an even stronger proposition is that this technological genre will emerge as a new ontological category (Kahn et al., 2006). so might people— and especially young children as they construct categories of knowledge based on interaction—experience the various attributes of personified technologies of the future in new ways.

2.3.3. Recent Research

In the following table (Table 2-3) we summarize in the a selected recent research on human-pet robot interaction, grouped by platform, and addressing the following aspects: participants' profile, main research questions, methodological approach and design, time span, type of data and main results.

Table 2-3 Overview of selected studies investigating interaction with Pleo and other robotic-pets.

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Jacobsson, M. (2009)	- Pleo - Presumably adults Bloggers in a particular blog	1. How's living with a companion robot 2. Identify significant features of people relationship with robots.	- Qualitative - Exploratory - Virtual Ethnography: content analyses from blogs and on-line forums		Posts gathered from a particular blog	Patterns: 1. Arrival and appropriation 2. When technology breaks down 3. Pleo as a socialization resource 4. Playing with Pleo
Fernaeus et al. (2010)	- Pleo - 6 families with kids from 1 to 17 years' old - Total children = 13	How Pleo is interacted with and reflected upon in a "natural" environment without constrains.	- Exploratory - Qualitative - Ethnographic - Long term - At participants' homes - Design-commercial perspective	From 2 months to 10	1. Clips video recorded by the families, pictures. 2. Interviews, at least 1, mostly 2, the first one after 2-3 months	Skeptical about the capability of Pleo of engaging people in the long-run
Pitsch, K., & Koch, B. (2010)	- Pleo - Normative children (N=3) - 3 years (girl), 4 and 8 years (boys)	1. How do users perceive the robot system? 2. How do perceptions change while interacting? 3. How are perceptions related to forms of contingent behavior?	- Qualitative interactional approach - Ethnomethodological Conversation Analysis (EM/CA) - Case analyses - Belongs to a bigger sample and are being analyzing as preliminary result of a more extensive study [no subsequent studies have been found]	The first contact situation	Video recorded data from 2 exploratory cases, one girl and a pair of children	Identify "stages" of interacting with Pleo in the first play session: 1. Handling an inanimate object 2. Socialization (experience Pleo as an animate object. 3. Developing interactional patterns 4. Interacting with Pleo "in different worlds"

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Dimas et al. (2010)	Pleo	- Does a digital extension of Pleo increase the attachment and potential for entertainment over time? - Overcoming 2 limitations: the battery and the unawareness of Pleo internal states that comes up with a lack of communication	- Work in progress - No study reported - Create a recognizable attachment behavior on Pleo from internal states awareness.	No study reported	No study reported	No study reported
Paepcke, S., & Takayama, L. (2010)	- AIBO/Pleo - Adults (N= 24) - 20 to 60 years - 12 males/12 females 72	1. Does expectation setting matter in human-robot interaction? 2. If so, how does expectation setting around robots' influence human perceptions and interactions with these robots? 3. Do they follow in the steps of psychological theories of the self-fulfilling prophecy and confirmation biases, or do they follow in the steps of the business philosophy of under-promising and over-delivering?	- Experimental between-participants design 2X2 expectancies (high/low) and robot (AIBO/Pleo) - DV = Expectations of robots (pre and post) - DV = Source Credibility Scale - DV = Interactive behavior - DV = Time in interaction - VE = User personality (Big Five) - VE = Gender - Thinking aloud protocol - Pre: interview about expectations on robots' behavior - Ten- Personality Inventory - Source credibility scale		- Observational data video-recorded - Interviews - Tests - Questionnaires	Expectations lower rather than higher led to less disappointment and more positive appraisals of the robot's competence.

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Díaz et al. (2011)	- Pleo - Normative children Two studies: 1. N=18 Girls 11-12 years, that freely preferred Pleo (from a group of 49 children) 2. N=4 Girls Recruited from the previous group	1. Explore first impression, Attraction, Preferences and Expectancies based on appearance. Observe children Interactive behavior with the robots 2. Observe the effect "meeting again" in three social context: alone, with a peer and with an adult	Exploratory 1. In the wild: workshop in a primary school 2. In the user experience lab	1. For the 18 girls in the school, of about 45' 2. For the 4 girls that went to the lab about 1 hour.	- Video recorded observational data - Questionnaires - Video recorded focus group	Relationship between genre and preferences
Heerink, M., Díaz-Boladeras, et al (2012)	- Pleo - Normative children (N=28) - 8 to 12 years	1. How children experience a pet-robot 2. How they play with it 3. How children's perceptions on and interaction with pet-robots are interrelated 4. Investigate Social presence from interactive behavior during play and from questionnaires.	- Quantitative/Qualitative - Exploratory - At special setting in the school - Free play in pairs	One 10 minutes' encounter	- Video recorded observational data - Questionnaires	- The two most prevalent behaviors were clearly social: petting the robot and showing it objects to engage in interaction. - Children spent on average less than one per cent of the session time treating the robot as an artifact. - No significant covariation between the experience of a social entity and observed behavior could be established.

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Rosenthal-von der Pütten et al., (2013)	- Pleo - Adults (N= 41) - 18 to 53 years - 20 males and 21 females	Object of study: - Socialness of reactions towards robots. Research question: - Whether humans show emotional reactions towards (Ugobe's Pleo) robots	- Experimental/ Quantitative 2X2 design - Multi-method approach (objective + self-report data) - IV1 between-subject = prior interaction with the robot (yes/no) - IV2 within-subjects type of video (friendly vs. torture interaction) - DV = emotional response Measurements - DV1 = Physiological arousal - DV2 = Emotional State (PANAS) - DV3 = Evaluation of o The videos (ad hoc 5-points Likert scale) o The robot (ad hoc 7-points Likert scale) o Empathy with the robot o Attribution of feelings Explanatory variables: - VC1= Affiliative Tendency - VC2 = Loneliness - VC3 = Empathy Trait (Interpersonal reactivity Index IRI)	- One encounter with Pleo of 10 minutes in one experimental condition. - Afterwards in both conditions exposed to videos with Pleo been treated friendly and tortured - 2 sets of 5 10 seconds clips, separated by a two-second pause.	- Objective: psychophysiological data (SCL and HR) - Self-report: diverse evaluation scales	- The videos elicit emotional responses (psychophysiological and self-reported) - The type of video affects the subjective experience (more empathetic concern, negative emotions and arousal after the torture video). - Surprisingly the prior interaction with the robot had no influence at all. - Surprisingly, individual variables (personality traits) need to belong, affiliative tendency and loneliness are not predictors of the emotional experience, nor of the general ability for empathy.

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Rosenthal-von der Pütten et al., (2014)	- Pleo - Adults (N= 14) - 20 to 30 years - 5 male/9female	Object of study: - Socialness of reactions towards robots. Research questions: 1. Whether humans show emotional reactions towards a robot 2. Whether these reactions differ from those towards a human	- Experimental/Quantitative 3X2 design - Multi-methodological study (objective + self-report data) - IV1 = within-subjects, type of dyad (H-H; H-R; H-B) - IV2 = within-subjects, type of interaction in video (positive vs. negative) - DV = emotional response Measurements - DV1= Brain activity - DV2= Emotional State (PANAS) - DV3 = Evaluation of o The videos (ad hoc 5-points Likert scale) o Empathy with the robot o Attribution of feelings	One	- Objective: psychophysiological data Functional Imaging Data (fRMI), - Self-report: Diverse evaluation scales	- Self-reported emotional states and functional imaging data revealed that participants indeed reacted emotionally when seeing the affectionate and violent videos. - No different neural activation patterns emerged for the affectionate interaction towards both, the robot and the human. - Differences were found in neural activity when comparing only the videos showing abusive behavior indicating that participants experience more emotional distress and show negative empathetic concern for the human in the abuse condition. - This was supported by similar findings with regard to participant’s self-reported emotional states.
Friedman, Kahn, & Hagman, (2003) Hardware companions? (Discussion Forum)	- AIBO - Presumably Adults - N=182	1. Investigate people’s relationship with AIBO 2. Would they treat robotic pets in some meaningful ways as if they were animals	- Qualitative - Value Sensitive Design (Content analyses?) - Pilot, generation of a coding manual/ analyses of formal data		- 6,438 spontaneous postings in online AIBO discussion forums - Selected 3,119 from 182 participants	- Participants often attributed technological essences (75%), biological essences (48%), mental states (60%), and social rapport (59%) to the robotic dog. - Participants seldom attributed moral standing (12%) to the robotic dog

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Kahn, Friedman, Pérez-Granados, & Freier, (2006 *Preeschool Study*	- AIBO - Normative Preschoolers (N=80) Two age groups: - N1= 40 2,5-4 years old equal number girls and boys - N2= 40 4,8-6 years old, equal number girls and boys	To which extend children act and think of AIBO as if it was alive, comparing to a stuffed dog	- Development study cross Sectional - Experimental within subjects - Observational (coding scheme) with different conditions of conductor's interventions+ interview + Card sorting - IV = artifact (AIBO/SHANTY) - DV = reasoning - DV = Interactive behavior - DV = Judgements	- 1 session - 45 minutes in total, a part with AIBO and another with SHANTY - Eventually could be split in two sessions in different days according to children needs.	- Observational Data - Self-reports on evaluations and justifications - Performance in card sorting - Non parametrics tests	- Children expressed reasoning, judgements and evaluation are similar but interactive behavior differ - Children engaged more often in apprehensive behavior and attempts at reciprocity with AIBO, and more often mistreated the stuffed dog and endowed it with animation. - Similarities in children's reasoning across artifacts were found.

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Melson, Kahn, Beck, & Friedman, (2009) *Development Study*	- AIBO - Normative children (N=72) Three age groups: - N1= 7-9 years old, evenly divided by sex - N2= 10-12 years old, evenly divided by sex - N3= 13-15 years old evenly divided by sex	To which extend children act and think of AIBO as if it was alive, comparing to a live dog	- Development cross Sectional study - Experimental in the lab within subjects - Observational (coding scheme) with different conditions of conductor's interventions+ interview + Card sorting - IV = kind of dog (entity) (robot/live) - DV = reasoning - No conductor intervention	2 sessions of 45 minutes each, one with AIBO and another with a live dog, one after the other	- Observational Data (coded "a portion" of the session) - Self-reports on evaluations and justifications - Performance in card sorting - Coded from transcripts	- Interactive behavior differ - A majority of children conceptualized and interacted with AIBO in ways that were like a live dog - Children conceptualized the live dog, as compared to AIBO, as having biological attributes, mental states, social companionship, and moral standing. - Children also spent more time touching and within arms distance of the live dog, as compared to AIBO - A majority of children conceptualized and interacted with AIBO in ways that were like a live dog. For example, over 60% of the children affirmed that AIBO had mental states, social companionship, and moral standing
Stanton, Kahn, Severson, Ruckert, & Gill, (2008)	- AIBO - Children diagnosed with autism (N=11) - Aged between 5 and 8 - 1 girl and 10 boys	Whether a robotic dog might aid in the social development of children with autism	- Within-subjects comparison study of the beneficial impact playing with AIBO and with a mechanical toy dog - Verbal questionnaire during play - The experimenter invite the child to engage in pre-established interactions	One individual interactive session with both artifacts lasting up about 30 minutes	Observational data from the videorecorded behavior Children behavior is coded according to an *ad hoc* coding scheme and manual organized in categories and subcategories.	- Children spoke more words to AIBO and more often engaged in behaviors with AIBO typical of Children without autism as compared to the mechanical non-robotic dog - Children more often engaged with the experimenter in the AIBO condition compared to the mechanical non-robotic dog condition

	Robot/ Participants	Research questions	Methodological approach / Study Design / Techniques	Encounters/ Duration	Data	Main results
Fransen, S., & Markopoulos, P. (2012)	- I-CAT - Normative children (N=12) - 7 and 8 years - 7 boys 5 girls		- At school - Robot as a facilitator of an school task to evaluate an activity "Robotic intervention protocol" - Think aloud protocol and interview - Peer tutoring			
Marti et al., (2005)	- PARO - Young patients with cognitive and personality disease (N=3) - 2 Down Syndrom (girl 27 years old/boy 23) - 1 Hanhart and Moebieus syndromes (boy 14)	Study the potential of the robot in mediating social relations, catalyzing the attention and stimulating the sensorial exploration (compared with conventional sessions) 2 Dimensions of behavior: - micro-level (gaze behavior, touch, speech.) - macro-level (activities: storytelling and pretend play)	- Exploratory (early attempt to investigate interaction dynamics with artificial pets in therapeutic contexts) - Qualitative - Comparison with previous sessions WITHOUT robot - Comparison with robot ON/OFF - Out patients Group Therapy at "Le Scotte" Hospital in Siena - DV: Therapeutical goals: enhance sociability and emotional awareness: - Sensorial Exploration - Social Exchange - Emotional Intelligence	One hour sessions weekly over a period of 3 months	- Observational data: all the sessions were video-recorded. - List of indicators and registration of occurrences, along with contextual information.	- Clear role of the robot in mediating social exchange and stimulating attachment and engagement. - Is not clear which qualities foster those effects and whether a stuffed or a real pet would have the same effects.
(von der Pütten, Krämer, & Eimler, 2011)	- NABAZTAG - Elderly	1. How do users interact with companions? 2. What would it mean for a companion to be sociable? 3. Do people show signs of bonding with a companion?	Qualitative / Quantitative	3 Iterations of 10 to 12 days	- Observational data - Interviews	

2.4. Robot Based Therapeutic Interventions for Children

There is an increasing interest in robot based applications for health and wellbeing. Social robots' capability to engage children in interaction and even in long-term relationship and of their versatility –scalability and adaptability- are extremely promising to enhance therapy related programs. The rational of this robots' based therapies are twofold: i) robots potential to subrogate animals in animal assisted therapies offering social, emotional and educational resources for hospital staff to use in patient care, and ii) the general willingness of children to engage with robots and treat them as social agents (Belpaeme et al., 2012).

Social robots have already been proposed as tool in pediatric hospitals for rehabilitation (Plaisant et al., 2000), autism therapy (Davis, Robins, Dautenhahn, & Nehaniv, n.d.), (Kozima, Nakagawa, & Yasuda, 2005) educative programs, treatment adherence and compliance (Ros et al., 2016) and even provide entertainment, enjoyment and comfort (Okamura, Matarić, & Christensen, 2010; Saldien et al., 2006; Shibata et al., 2001).

Based on promising perspectives open by these experiences, Robot Assisted Therapy (RAT) or Robot-Enhanced Therapy (RET, the so called next generation of RAT[11]) and Social Assistive Robotics (SAR) are fast growing sub-fields of HRI. The purpose of SAR is to provide care and assistance and reduce the burden of family members and caregivers automatizing functions as supervision, coaching, motivation and companionship, through one-on-one interaction with the robot, through social –stablishing a relationship with the user- rather than physical interaction. Among the patients that can benefit most from SAR are children with special needs, in both diagnostic and therapeutic uses (D. J. Feil-Seifer & Matarić, 2011).

In social robot-based programs the robot can adopt different roles in pediatric services: trainer, tutor or assistant (coach) or a close buddy that offers support and company (companion). Consistent with their role, coaches and companion robots require different embodiments and behavior to engage children to fulfil their goals beyond the novelty effect (for a more complete comparison between coach and companion robots for pediatric service see (Díaz et al., 2011).

In the rest of this section, a brief overview of the most promising areas of application is presented

[11] http://www.dream2020.eu/what-is-ratret/

Children with development disorders or other disabilities.

One of the most promising application domain of social robotics is *therapies* with children with autistic spectrum disorder (ASD) (e.g. projects AURORA and DREAM, see Table 2-1 for more details) where the basic hypothesis are that a robot can be developed as a useful therapeutic tool, provided that playing with an interactive robot can be beneficial to children, differently from playing with other toys, an *added value* that has a very well founded rationale and empiric evidence (K. Dautenhahn & Werry, 2002). The two main hypotheses -interactions with the robot are not only *special* but also more effective in therapy- are validated by comparison studies on how children interact with different toys and devices, and on the therapeutic-related outcomes.

> Well-designed robotic agents have proven to be particularly effective and are becoming an increasingly important tool for mediating between therapists and ASD children in robot-assisted therapy (RAT). However, therapeutic interventions require significant human resources over extended periods. Consequently, to make a significant difference, therapeutic robots need to have a greater degree of autonomy than current remote-controlled systems. Furthermore, they have to act on more than just the child's directly-observable movements because emotions and intentions are even more important for selecting effective therapeutic responses. The next generation of RAT, which we refer to as robot-enhanced therapy (RET), will be able to infer the ASD children's psychological disposition and assess their behavior in order to select therapeutic actions. Since children require therapy tailored to individual needs RET robots will provide this too. http://www.dream2020.eu/what-is-ratret/

Coaching in Rehabilitation, Adherence to Treatment and Educative Programs

The social robot taking the role of children trainer or coach evokes the Pupil-Coach interdependence based on the social bond (i.e. affective involvement), task, and goals. Obtaining patient collaboration is an essential issue in therapy and educative programs that requires an agreement about the relevance and usefulness of tasks and goals (therapeutic alliance). To fulfill the therapy's goals, the coach must provide ongoing supervision, encouragement, feedback, counseling, and support. Furthermore, to enhance children agreement and compliance is necessary to create an affective bond. Rehabilitation and lasting changes in habits are usually hard to undertake. Engagement and motivation can benefit from an affective bond of trust and intimacy -the necessary *therapeutic alliance*- between pupil and coach. The coach must be responsive to pupil needs and emotions in an empathic way and find an acceptable balance between goals commitment and concern for pupil's wellbeing. In this context, the most prominent skills are engaging communication, contingent feedback, empathic rapport and awareness of child's psychological and physical state (Diaz et al., 2011; Kidd & Breazeal, 2008)

The European funded ALIZ-E project[12] (see Table 2-1) is based on robot's capability –Nao robot in this case- to engage children in a coach-patient long-term social interaction in a hospital setting, targeting a population of 8-11 year-olds diagnosed with metabolic disorders (diabetes and obesity). Nao's role is a friend and a mentor that improve the children's experience during the hospital stay, supporting their well-being and aiding in their learning about the management of their health condition (Belpaeme et al., 2012; Ros, Baxter, Nalin, & Wood, 2011).

Company and Support for Hospitalized Children

For in-patient children whose health condition requires long hospitalization or frequent stays at hospitals for follow up, treatments or rehabilitation, the robot can offer an experience of distraction, diversion or close companionship. Long-term hospitalization is a serious event that affects children and their families' lives who are confronted with stressful conditions including physical pain and fear, and social support becomes almost limited to hospital staff and relatives, -who often are affected themselves by feelings of sorrow and concern- In these cases, in patient children can benefit from the company of an artificial buddy (Díaz et al., 2011; Jeong, Zisook, et al., 2015).

While is gaining support the assumption that under certain conditions, robots provide an attractive alternative for Animal Assisted Therapy -that is a method often used to improve the well-being of children during a stay in hospital-, it is not without a certain degree of controversy.

> It is also unclear whether animal analogues, such as puppets, virtual pets, or robotic pets, can function as a social partner in a relationship. Turkle (2013) contends that digital and robotic social "others" cannot truly be responsive, and provide shallow relationship experiences (Melson & Fine, 2010)

Any case, there are few antecedents of robots being deployed in pediatric hospitals supporting children and relatives well-being during hospitalization in a long-term basis. According to a recent survey (Leite et al., 2013) the studies on long-term effects of social robots as companions in health organizations are focused on elderly people in nursing homes, featuring both robotic-pets like PARO (Wada & Shibata, 2009), anthropomorphic like ROBOVIE (Sabelli, Kanda, &

[12] 1http://www.aliz-e.org

Hagita, 2011). Moreover, in the few studies on social HRI in the scenario of pediatric hospitals the robot took the role of a coach or assistant in rehabilitation routines (Calderita et al., 2015), education[13] or a short time distractor during stressful or painful situation like vaccination (Beran, Ramirez-Serrano, Vanderkooi, Kuhn, & Beran, T. N., Ramirez-Serrano, A., Vanderkooi, O. G., & Kuhn, 2013).

Even though some ad-hoc robots designed to assist children during hospitalization has been presented to the HRI community as the elephant's head PROBO (Saldien et al., 2006), and the teddy bear Huggable -targeting in patients who suffer from chronic and severe pain admitted to inpatient care for long periods (Jeong, Zisook, et al., 2015)-, as far as we know, no conclusive results has been reported on the deployment of companion robots in pediatric hospitals. Another innovative project –recently ended- is the European Funded MOnarCH *Multi-Robot Cognitive Systems Operating in Hospitals*[14] that focused on using networked heterogeneous ad-hoc designed robots and sensors to interact with children, staff, and visitors, engaging in edutainment activities in the pediatric infirmary of an oncological hospital, investigating the potential of hybrid human-robot collaborative systems as suppliers of health services.

Another pioneering experience was carried out investigating the deployment in a hospital of an autonomous delivery robot with scare capability to communicate with people –just speech based warnings to smooth navigation though the hospital facilities. In this ethnography, the emphasis was put on the impact of this new resource to the organization -how organizational, social, and environmental factors affect how people work with and perceive robotic technology- rather than on the specific interactive behavior with the robot or the therapeutic-related impact, following the rational of the technology appropriation field (Mutlu & Forlizzi, 2008).

These antecedents point out the particular challenges of deploying robots to accompany children in hospitals. In addition to safety and technical issues related to navigating and interacting socially in open busy public spaces (Díaz-Boladeras et al., 2015) particular ethical issues arise due to the sensitive nature of pediatric care context (Jeong, Connell, Anderson, & Graca, n.d.; Ros, Nalin, et al., 2011).

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[13] http://www.aliz-e.org/

[14] http://monarch-fp7.eu/

2.5. Methodological Issues in Social HRI Research

As seen above, HRI community face nowadays developments and applications that imply handle psychological constructs not only as the specific mechanisms involved in performing smart interaction with humans, but also as the outcomes of robot-based educational and health programs.

2.5.1. Heterogeneity of Methodological Approaches

"How can robot-human interaction be analyzed?" That is the crux of the matrix stated by (K. Dautenhahn & Werry, 2002, 1134), not (just) as a rhetorical question. The heterogeneity caused by the research field immaturity and the diversity of approaches of the disciplines involved in evaluating HRI has been highlighted with concern by leading researchers like one of the drawbacks that limit the scientific advances and consequently the impact of social robots and as a symptom of the immaturity of a science. Furthermore, Lohse conclude from literature review that HRI cannot be considered –so far- a real discipline but rather just an area of research because of this lack of "specific methods or research techniques" (Lohse, 2010, 2). Elaborating this idea Dautenhahn considers that descriptive narratives has been –and are- useful in order to give exploratory insights on how people interact with robots under different conditions –contexts, platforms, target users- but in order to improve the robot-based interventions in application domains -such as education or therapy- a more systematic approach is needed.

This methodological heterogeneity accumulates over the past 20 years a wide range of information regarding the use of and the perceptions towards different robots in different contexts, but also limits the replicability of results across the field as a whole. It is understood that the technology driven nature of the field, and as such, the need to evaluate specific technologies in specific contexts, is a motivating factor for conducting context-specific studies. However, it is important to note that this may become a limitation for the HRI community in the long-run as the lack of common benchmarks and measures may hamper communication and application of results across different research groups and projects, and thus the advancement of the field as a whole may be slowed down (Kerstin Dautenhahn, 2007b; Syrdal & Dautenhahn, 2009).

Moreover, we consider that this heterogeneity of methodological approaches and techniques in HRI research come not only from the above mentioned immaturity of the discipline but more importantly from its very essence as a discipline in the boundaries between two different –when not confronted- conceptions on what is scientific knowledge. As any discipline, technological driven disciplines tend to apply the well-known and agreed upon scientific paradigm –positivism- and the methodological approaches –quantitative- that are informed by this paradigm to cope with new problems and challenges. The conflict arises when these new key problems and challenges the robotics community is so eager to investigate include intrinsically subjectivity and sociality, concepts far beyond the traditional phenomena addressed efficiently with the methodological tools –and perspective- provided by positivist research.

In the particular case of social HRI we can point out a confluence of the traditional dominance of technology communities to extend *naturally* its perspective, together with a somehow inattentive or shy attitude of behavioral scientists that seem to hesitate to lead the emergent field of human interaction with personified technologies. As one of the most outstanding researchers on emotional social HRI states "robots are about people" (Breazeal, 2010) and engineers seem to have come to this conclusion sooner than psychologists. We cannot but support Kahn's vehement call to psychologists to recognize the exponential growth of technological systems in children's lives, and to be future oriented to remain relevant (Kahn, Gary, & Shen, 2013, 32).

Fortunately, the divide between social and technology driven research is being not only recurrently highlighted as an obstacle to achieve better results, but efficiently coped with and becoming more and more permeable. In this sense it is noticeably for instance the shift in the composition of the research teams in HRI towards real interdisciplinary recruiting researchers for key positions from the disciplines traditionally devoted to observing, explaining and measuring behavior. We consider that –hopefully- we will assist in the next years to a leading role of behavioral and social scientists in social HRI research. In fact from our perspective sociality with robots is an object of study of Social Psychology.

2.5.2. Mechanism vs. Functional Evaluation

A centric question is delimiting what is to be evaluated when assessing HRI. From the technological traditional perspective evaluating a system -in this case a hybrid system with –at least- one human and one personified technology- is to assess how good is the system performance against observable and operational criteria (metrics). A robotic system has been assumed until recently to be purposeful and to be defined –and designed for- a specific utility: a range of tasks that have to be fulfilled as efficiently as possible according to predefined constraints.

However, even though social robots are included in task oriented interventions such as tutoring children or coaching inpatients for rehabilitation, there are other applications that are hard to be evaluated in terms of execution. How might be evaluated a companion robots that are not expected to be useful but to provide *radically new forms of experiences* (F Kaplan, 2005)?. Moreover, how might be evaluated companion robots that are supposed to be intrinsically and essentially *useless*? (Frédéric Kaplan, 2005, 27).

In the robotics community robot-human interaction is often assessed focusing on a particular process that can been measured through questionnaires (e.g. how good is a robot expressing emotions) or through robot's performance (e.g. how good is a robot navigating among a crowd). However, such techniques cannot be applied in many services applications where the robot does not have an explicit *task* nor to solve any *problem* but to interact with participants in such a way that address mediated issues (e.g. therapeutically relevant issues) (K. Dautenhahn & Werry, 2002, 1134).

2.5.3. Evaluating Social HRI

Complex and elusive psychological constructs are being considered increasingly as study variables in mainstream social HRI research, such as expectations, perceptions, attitudes, judgments, engagement, attributions, and empathy. Moreover, in the application fields of therapy, wellbeing or education other criteria related to the purpose of the system are involved such as anxiety reduction, optimism, design thinking, motivation, self-efficacy, health self-perception (see Table 2-5).

Just as a recent instance of this concern, the call of a monographic workshop on Empathic Human-Robot Interaction:

> Empathy is also becoming increasingly relevant in robotics and in particular the areas of social robotics and human-robot interaction where we aim at developing systems that are not only efficient at the execution of certain tasks, but are able to "understand" the person they are interacting with, and convey their ability to the person. This touches upon hard problems in robotics and computer science, e.g. social signal processing in verbal and non-verbal human-robot interaction, modelling of another's internal states, establishing methods for quantifying an empathetic relationship and thus determining success of solutions, beliefs and goals and creating human-robot interactions whereby people feel that the robot actually "cares" about them. (*Empathic Human-Robot Interaction: A Joint Industry-Academia Outlook for the Future*, held in Edinbourgh on 24th march 2017)

We identify at least three blocks of variables that are by no means independent but that can be studied separately, applying different evaluation methods and/or techniques:

1. Individual variables: personality, attitude towards robots, technology familiarity, attitude towards company animals.

2. Cognitions on the robot: judgments, evaluations, reasoning, attributions about any robot's feature such as states, motivations, drives, capabilities, traits, intent, or essence.
3. Subjective experience as the "socio-emotional aspects of the interaction" (Rosenthal-von der Pütten, A. M., & Krämer, 2014, 21), psychological states related to the interaction, the situation and the robot, including emotions and feelings towards the robot.
4. Actuated interactive behavior, verbal and non-verbal

The techniques of evaluation are these of psychological evaluation and we can apply the same criteria to classify them, according to the intervention or not of people's judgment or mediation (subject, researcher) in data production.

Observation

Generally speaking, we believe that in many application domains involving robots and humans, observational data is highly valuable at least for the following reasons: i) to avoid self-reporting shortcomings such as social desirability response bias -where people respond to studies in a way that presents them in a positive light-, or the interviewer bias -where the interviewer influences the responses-, ii) with non-verbal subjects (e.g. preverbal children, people with communicative disabilities like autistic children) iii) when direct inquiry it is too intrusive (e.g. when young children are involved), iv) when responses are very likely to be biased by influences from the experimenters or attitudes or expectations of the subjects on the outcome of the study, and finally but not less important, iv) when there is empirical evidence that shows up that observational and self-report may differ significantly (K. Dautenhahn & Werry, 2002; Kahn, Jr. et al., 2006)

The main limitations of current observation studies in HRI are:

- Most studies are only focused on the child's behavior and no information is gathered from what was doing the robot or from situational variables.
- Most quantitative analyses based in frequency and time duration measures regard any piece of behavior as independent events, what is clearly a limitation, provided during the flow of interactions the particular context in which a behavior occurs is often fundamentally crucial to make sense of the particular behavior. Moreover, a particular behavior that happens only once may be very relevant from the point of view of the intervention, as in therapy (K. Dautenhahn & Werry, 2002, 1137).

– The difficulty to determine the granularity in the behavior units. Dautehnhan (K. Dautenhahn & Werry, 2002) opts for what she called *micro-behavior* that has the following advantages:

  - Are well identifiable, are rather low-level and "action/movement· oriented categories
  - Are not very specific to a particular situation/user/domain (e.g. autistic children) and can thus be identified more easily by researchers or not experts (e.g. not experts on autistic children behavior).
  - Are more likely to be recognizable by a computational vision system that can overcome the time-consuming hand coding of the video data.

Table 2-4 Classification of methods and techniques in social HRI evaluation

Type	**Source**	**Data**	**Technique/Variable**
Direct	From subjects	Psycho physiological Parameters	Heart Rate
			Brain Activity
			Skin conductance
			Breath Rate
		Motor Activity	Movements
			Postures
			Micro-movements
			Position
			Trajectories
			Gestures
			Gaze
	From robots	System logs*	
		Traces	
Indirect	Self-report	Questionnaires	Scales
			Ranking Card sorting
			Semantic differential
			Open ended
		Interviews	
		Talking aloud protocols	
		Diaries/Blogs	
	Judgment/ Rating/Coding	Systematic observation of verbal and nonverbal behavior	Coded behavior Discourse analyses
		Expert estimates	
		Other ratings	
		Ethnographies	Field Notes

* Digital evidence or event registered during a particular time span

Interesting attempts have been made to include the social context in the analyses with qualitative techniques from the field of communication such as conversational analysis. These techniques are very pertinent to study interaction unfolding over time, providing a more detailed investigation of the local context and social situatedness of the acts of interaction and communication, and highlighting the temporal quality of behaviors, the *flow* of the interaction (temporal interdependence).

Questionnaires

We differentiate between general scales, scales designed to be used across different media/technology and scales designed to be used in social robots research.

a) General Scales or standard instruments from social psychology (Rosenthal-von der Pütten, A. M., & Krämer, 2014 [21]):
    - *The Positive and Negative Affect Schedule (PANAS) 15*
b) Scales designed to be used across different media/technology
    i) Immersion
    ii) Social and Physical Presence
c) Scales especially created for use in human-agent/robot interaction studies.
    - *Agent Persona Instrument API*
    i) Attitude and disposition
        - *Attitude Towards Agents Scale (ATAS)*
        - *Negative Attitude towards Robots Scale (NARS)* (Syrdal & Dautenhahn, 2009)
        - *Interpersonal Reactivity Index Adapted for HRI*
        - *Multi-dimensional Robot Attitude Scale* (Takumi Ninomiya, Akihito Fujita, Daisuke Suzuki, 2015),
        - *Robot Anxiety Scale (RAS)* (Rosenthal-von der Pütten, A. M., & Krämer, 2014)
    ii) Evaluations
        - *Social Robotics Questionnaire*[16]
        - *The Goodspeed Series. Measures: anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety*
        - *Perceived efficiency*
        - *Believility and trust*

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15 http://www2.psychology.uiowa.edu/faculty/Clark/PANAS-X.pdf
16 http://socialrobotics.tamk.fi/questionnaire.html

d) Questionnaires on pet bonding[17]

- *Lexington Attachment to Pets Scale (Melson G. F., Kahn Jr, Beck, & Friedman, 2009)*

Measurement of expectations through questionnaires is difficult because expectations are reactive to them (Olson, Roese, & Zanna, 1996). This means that the measurement process itself may induce expectations that would not have been generated spontaneously. That is why self-report measures alone are fallible (Feather, 1982c) (Lohse, 2010, 55) and one recommendation is to complement survey results in strategic application domain –such as acceptance of childcare robots- contrasting with ethnographic observations of such robots in use.

In their outstanding studies on children and teenagers conceptualization and interaction with pet robots, Kahn (2006) demonstrated that children's reasoning about robots (e.g. the robotic dog AIBO) and their behavioral interaction with these systems differ (children assess similarly stuffed dog and AIBO, but behave differently). These results, clearly question the validity of studies on attitudes towards and perceptions of robot systems using only self-report techniques (questionnaires and/or interviews) at least when evaluating CRI.

Experimental settings

Conducting and evaluating interaction studies that meet the requirements and standards of human-human interaction studies is still a big challenge, basically because it is extremely difficult to program robots to exhibit autonomously the studied behaviors in a flow of an interaction episode reliably, robustly, safely, while readily and in real-time responding to often subjective and highly dynamic behaviors of the human partner (Kerstin Dautenhahn, 2007a).

One way to face this drawback in experimental settings is to apply the Wizard of Oz techniques, in which one operator –human- control remotely the behavior of the system -unknown to the test subjects-, ranging from full teleoperation to partial control (Riek, 2012).

In words of Dautenhahn, it is more unfortunate that the design and methodological problems of most studies did not allow for any strong conclusions to be drawn. Prominent limitations of current studies on CRI are:

– Most observations were constrained to a single exposure in spite of the fact that the real utility of such robots would be in the long run. One may expect rapid habituation over time which may compromise the utility of such invention

[17] For a thorough review of scales on bonding with animals see (Anderson, 2007)

- In most cases, the behavior of the pet-robots is not reported.
- Little care is taken to control for differences in familiarity and novelty.
- The participation of another human in the social interaction in many settings –like in therapy related applications- may actually "overshadow" robot's interaction

Challenges Evaluating Child-Robot Interaction (HRI)

As mentioned above, CRI is a growing sub-field in HRI involving in a variety of academic disciplines, including psychology, nursing, child development, social work, and education, especial challenges are faced based on –at least- two major differences: children seem to be more prone to engage with robots in general than teenagers and adults (Ros, Baxter, et al., 2011) and all the general difficulties–not negligible- and cautions to be taken into account when investigating with children (Mukherji & Albon, 2015).

To illustrate the interest and the awareness of the uniqueness of evaluating CRI, we cite here the call for participation words for the 1st Workshop on Evaluating Child-Robot Interaction, where the problems and challenges of robots are considered from the developers' perspective highlighting the following issues:

- When working with children, researchers have to pay specific attention to ethical issues and safety.
- Commonly used methods such as questionnaires do not work well particularly with younger children, due to a strong tendency to be either very positive or very negative on subjective measures and need support in expressing how they feel about technology.
- Behavioral measures from observations to evaluate CRI are not necessarily comparable between studies and robots.
- Particularly in long-term studies, children change with respect to e.g., literacy, memory, or their abilities for dealing with social interactions and their own emotions.

As a conclusion, there is a need to develop methods that can be used to evaluate and benchmark the quality of CRI in a safe, ethical, and reliable way (1st Workshop on Evaluating Child-Robot Interaction at ICSR, Paris, October 26 2015)[18].

[18] https://evaluatingchildrobotinteraction.wordpress.com/

Table 2-5 Overview of concepts, variables, methods and techniques in social HRI evaluation

Dimension/ variable	**Study**	**Robot**	**Participants**	**Method/ Dom/Role**	**Self-Report**	**Observation**	**Psychophys.**	**Others**
Expectancies	Lohse, 2010	BIRON (BIelefeld RObot companioN)	24 subjects students and seniors	Quantitative Lab	Users' evaluation of the robot after the task which included items on liking the robot, attributions made towards the robot, and usability of the robot	Analysis of the users' behavior repertoires (speech, gesture, eye gaze, body orientation		Interviews with the users after the trials
	Paepcke, S., & Takayama, L. 2010	Pleo, NAO	Adults 20-60					
	Díaz et al., 2011	Pleo, NAO, AIBO, SPYKEE	Children 11-12 years	School and Lab/ Therapy/Pet	Ad-hoc Questionnaire	At school In the lab		Focus Group
Immediacy	Kennedy, Baxter, Senft, & Belpaeme, 2015	NAO + Surface touchscreen	Children 7-9 years	Lab/ Educational /Tutor	Immediacy Questionnaire (Adaptation)			
Evaluation of The Robot	Rosenthal-von der Pütten et al., 2013	Pleo	Adults 18-53 years	Lab/ Experimental	Ad-hoc 7-point Likert scale (Cheerful, Antipathy etc)			
	Heerink, M., Díaz-Boladeras, et al 2012	Pleo	Children 8-12 years	School/ Therapeutic /Pet	Ad-hoc Questionnaire Select between adjectives (animated/inanimated)			
	Kahn, Friedman, Pérez-Granados, & Freier, 2006	AIBO/Stuffed Dog	Children 2,5-6 years	Development /Pet	Self-reports on evaluations and justifications Performance in card sorting	Observational Data Behavioral Analyses coding scheme		
	Melson, Kahn, Beck, & Friedman, 2009	AIBO/Dog	Children 7-15 years	Development /Pet	Self-reports on evaluations and justifications Performance in card sorting	Observational Data Behavioral Analyses coding scheme		

Dimension/ variable	Study	Robot	Participants	Method/ Dom/Role	Self-Report	Observation	Psychophys.	Others
Anthropomorphism **Animacy** **Likeability** **Perc. Intelligence** **Perc. Security**	Alves-Oliveira & Paiva, 2015	NAO + Surface touchscreen	Children 7-9 years	In the wild/ Educational	- Goodspeed series Questionnaire - Interviews	Behavioral Analyses (?) Not Reported		
Attribution of Feelings	Heerink, M., Díaz-Boladeras, et al 2012	Pleo	Children 8-12 years	School/ Therapeutic /Pet	Social presence, Subjective experience Ad-hoc Questionnaire			
Empathy	Alves-Oliveira & Paiva, 2015	NAO + Surface touchscreen	Children 7-9 years	School/ Educational	Interpersonal Reactivity Index Adapted for HRI 1. empathic concern 2. perspective taking dimensions	Behavioral Analyses (?) Not Reported		
	Rosenthal-von der Pütten et al., 2013	Pleo	Adults 18-53 years	Lab/ Experimental	Ad-hoc 5 points Likert Scale 1. Pity for robot/Angry at torturer 2. Empathy with robot,			
Attitude	Alves-Oliveira & Paiva, 2015	NAO + Surface touchscreen	Children 7-9 years	School/ Educational	NARS	Behavioral Analyses (?) Not Reported		
Acceptance	Alves-Oliveira & Paiva, 2015	NAO + Surface touchscreen	Children 7-9 years	School/ Educational	Tech. Accept.Scale	Behavioral Analyses (?) Not Reported		
Enjoyment/Fun (?)	Alves-Oliveira & Paiva, 2015	NAO	Children 6-7 years	School/ Educational	Smileymeter Again-Again Table	Behavioral Analyses (?) Not Reported		

Dimension/ variable	Study	Robot	Participants	Method/ Dom/Role	Self-Report	Observation	Psychophys.	Others
Emotional Response (Arousal and Subjective Feelings)	Rosenthal-von der Pütten et al., 2013	Pleo	Adults 18-53 years	Lab/ Experimental	- PANAS - Ad-hoc Questionnaire - On Empathy, Feelings Attribution, Judgements on the video, Judgements on the robot		Physiological arousal: Electrodermal Activity and Heart Rate	
	Rosenthal-von der Pütten et al., 2014	Pleo	Adults 20-30 years	Lab/ Experimental	- PANAS - Ad-hoc Questionnaire - On Empathy, Feelings Attribution, Judgements on the video, Judgements on the robot		Brain Activity	
Anxiety Affect Pain	Jeong, Logan, et al., 2015	HUGGABLE	Children 3-10 years In Surgical, Oncology post-surgical units	Pediatric Hospital bed space/ Therapeutic	- STAIC - PANAS (for CH) - Numerical rating scales for pain intensity - Faces Pain Scale	Not Reported		
Perceptions On Robot	Pitsch & Koch, 2010	Pleo	Children 3-8 years	Qualitative interactional/ Pet		Video recorded first encounter free play EM/CA		
Social Agency	Heerink, M., Díaz-Boladeras, et al 2012	Pleo	Children 8-12 years	School/ Therapeutic /Pet	Social presence, Subjective experience Ad-hoc Questionnaire	Video recorded first encounter free play Coding scheme		
Interactive Behavior	Kahn, Friedman, Pérez-Granados, & Freier, 2006	AIBO/Stuffed	Children 2,5-6 years		Self-reports on evaluations and justifications	Observational Data Behavioral Analyses coding scheme		
	Melson, Kahn, Beck, & Friedman, 2009	AIBO/Dog	Children 7-15 years		Self-reports on evaluations and justifications	Observational Data Behavioral Analyses coding scheme		

Dimension/ variable	Study	Robot	Participants	Method/ Dom/Role	Self-Report	Observation	Psychophys.	Others
	Pitsch & Koch, 2010	Pleo	Children 3-8 years	Qualitative interactional/ Pet		Video recorded first encounter free play EM/CA		
	Heerink, M., Díaz-Boladeras, et al 2012	Pleo	Children 8-12 years	School/ Therapeutic /Pet	Social presence, Subjective experience Ad-hoc Questionnaire	Video recorded first encounter free play Coding scheme		
As Social Facilitator	Marti et al., 2005	PARO	N=3 14 to 27 2 males/1 female 2 Down Syndrom (girl 27 years old/boy 23) 1 Hanhart and Moebieus syndromes (boy 14)	Exploratory Qualitative Comparative		Observational data: all the sessions were video-recorded. List of indicators and registration of occurrences, along with contextual information		

2.5.4. Ethics in Social HRI

There is an increasing concern in HRI community about the ethical questions raised by the presence of social robots in our daily lives and specially the ethical implications of interacting with robots over repeated interactions for extended periods of time (Leite et al., 2013). The investigation of social effects of robots is quite new, but is steadily attracting more interest and with it the interest as well to investigate the eventual detrimental impact of people *exposure* to social robots, especially when vulnerable user' groups are involved and in therapeutic and care purposes.

The critical discussion has arrived to mainstream research fora while until recently seemed to be restricted to the studies on science and technology community and some pioneer researchers a decade ago that considered that the most prominent non-physical risks posed by social assistive system include but are not limited to attachment to the root, deception about the abilities of the robot and influence on the human-human interaction of a robot's user (D. J. Feil-Seifer & Matarić, 2011; Sharkey & Sharkey, 2011).

Significantly, in the HRI conference of 2017 a section entitled *The Less Positive Side of HRI* was included in the main track:

> Beyond human acceptance, statistical significance and algorithmic performance lay deeper questions of positive and negative downstream impacts, and the transformational impacts that HRI work can have on society. Given possible detrimental effects, what new methodologies or techniques can be proposed to encourage awareness and more positive results? We encourage researchers to consider the bigger picture of their work. Not just "can we do this?" but "should we?" (*Reflective and grounded analysis of the positive and negative impacts of previous HRI work*. http://humanrobotinteraction.org/2017/authors/alt-hri/)

In this section we review concerns regarding ethical issues in HRI research with an emphasis on children wellbeing and the therapeutic settings.

Jeopardize children healthy development and social relationships

One no negligible concern is whether children relationship with social robots could jeopardize their healthy development with a detrimental effect on their wellbeing. For instance, the development of reciprocity as a foundation for moral-development, occurs substantially within the sphere of peer-peer interactions, setting into motion attitudes and perceptions so important not only for individuals but for our species as concerns for the well-being of others and the construction of equality, fairness, and justice.

Would children growing up with robots –that they know are objects and consequently ontologically and morally inferior as a human creation- carry over they dominating way of interacting with robots to how they treat another human?

> Treating robots as subservient could lead to: i) a decrease of respect in treating robots and ii) treating as subservient humans that take similar roles. (Dahl, 2014)

> We raise the concern that because these robots [social robots] can be conceptualized as both social entities and objects, children might dominate them and reify a master-servant relationship. And that in such ways, this could lead to detrimental developmental outcomes, even as the robots benefit children another ways. (Kahn et al., 2013)

Other detrimental effects pointed out by Sharkey and Sharkey in addition to impeded social, emotional, and linguistic development, a young child spending too much time with a robot might suffer other negatives consequences as showing a preference of interacting with a robot rather with other human (being robot interaction more predictable) and plainly developing differently as other examples in the natural world of individuals brought up among other species' individuals. These risks to a healthy development are envisaged at least for babies and infants but it would be not necessarily true for older children "who have a good grounding in human-social interaction" (Sharkey & Sharkey, 2011).

It is to be noticed that these risks are always contextualized by the authors to a massive exposure of babies to robot's presence, as an exclusive or near exclusive children primary care-giver, *replacing* human presence and interaction. Otherwise they consider that "some exposure to robots might even be useful". To put the debate in perspective, the vehement position of Sharkey and Sharkey (Sharkey & Sharkey, 2011) were referred to as a "hyperbolic yet poignant" by (D. J. Feil-Seifer & Matarić, 2011), as an improbable and extreme scenario –the robot as a nanny-substitute-what is far to be considered neither feasible nor ethically acceptable in the HRI community.

Deception

Studies have shown that people quickly form representations of the *minds* of robots they are presented with, much as they do of people, that are often incorrect and attribute to the robot social entity –imputing feelings and intelligence- that they does not have.

> Ethical concerns may emerge when creating social robots that could be perceived by humans as Pets. This issue has to be addressed (Matellán & Fernández, 2014, 213)

> There are also ethical issues associated with the mapping principle to emulate more and more credible life-like creatures. As social robots more closely approximate their living analogues, do such robots run the risk of "fooling" their human users? (Melson, 2014)

> The question then is, should attempts to create an illusion of robot sentience to foster the belief that a robot is something or someone worth forming a relationship would be viewed as both deceptive and unethical? (Sharkey & Sharkey, 2011)

The human-likeness and life-likeness of the robot and in general their appearance and affordances –along with an increasing believability of interaction- influence the way the robot is perceived and received by users, and persuade them to form seeming relationships with it (Sharkey & Sharkey, 2011). However, communication is also crucial in the creation of expectancies and attributions. Sometimes such personification arise from caregiver or other present referring to the robot as him or her, or interpreting their performance in terms of desires, needs, intend. Actually, it does not matter if designers or caregivers manipulate on purpose the perceptions of the user or not, the case is that if the user perceptions are incorrect, the user is deceived (D. J. Feil-Seifer & Matarić, 2011).

More specifically, where charming robots are deployed to undertake the role of child close friend –exploiting the natural human tendency to anthropomorphize objects favoring the creation of emotional bonds- , to which extend –if any- can researchers deceive children making them believe that a) the robot has emotional agency and real empathy b) the robot is as trustworthy and fair as it seems (i.e. is not going to reveal a secret) instead of an interface of a system that use its compelling embodiment to acquire and deliver data to other agents (not involved in the primary social interaction) that would not be able to obtain if children was really aware.

In the context of the Monarch Project whose mission is to contribute to improve the quality of life of inpatient children by having robots interacting with them in distinct contexts in a hospital environment, the question was clearly stated:

> Is it ethically acceptable to create a robot that leads children to believe that it has mental states and emotional understanding? (Ferreira & Sequeira, n.d.)

And a possible approach is to relate fairness to the intention:

> If the illusion of a robot with mental states is created for a movie or a funfair or even to motivate and inspire children at school then there is no harm. The moral issue arises and the illusion becomes harmful deceit both when it is used to lure child into a false relationship and if such an

> illusory relationship is used in combination with near-exclusive exposure to robot care (Ferreira & Sequeira, n.d.)

Emotional Impact and Dependency

As we have reviewed in previous sections, evidence is already gathered that social robots affect emotionally people. While establishing engagement and having the user enjoy interactions with the robot, attachment can also result in problems with users of all ages under certain circumstances, especially in therapeutic contexts. The robot absence when the therapy concludes, or when the robot requires technical intervention, may, in cases of attachment, cause user distress and possibly result in a loss of therapeutic benefits, not only in users who cannot understand the causes for the robot's removal but even with users who have full understanding of the circumstances (D. J. Feil-Seifer & Matarić, 2011).

> Before progressing too far down the road toward robot care, it is important to consider what ethical problems are involved in allowing, or even encouraging the youngest and the eldest members of the society to think that they can for relationships with robots (Sharkey & Sharkey, 2011)

It is especially important to foster research on the questions of how, to which extend and how beneficial or detrimental is this impact that immediately raise ethical issues:

> Is it justifiable from an ethical stance to build a robot that the user feels sorry for when it is switched off? Is it appropriate to design a robot that is so engaging that people become emotionally attached to it, forming a relationship that is comparable to a human-human relationship? How do we want people to perceive and interact with robots? and what kind of reactions would we like to prevent? (Rosenthal-von der Pütten et al., 2013)

> It's necessary to graduate the level of dependency according to the duration of the relationship for reducing the emotional impact of separations for instance in hospitalized interventions. (Dahl, 2014)

From the point of view of children health development there is a claim to the field to devote attention to how the relationship with robots can benefit or diminish children's social wellbeing:

> ... it will become increasingly important for the developmental community to engage in research that assesses not only the benefits but the psychological costs of human-robot interaction. (Kahn et al., 2013).

Interfere with Children-Real Pet Connection

Another risk pointed out by experts on human-animal bond of an increasing penetration of artificial pets in children's lives is the eventual interference of these artificial creatures on our natural affiliation with the natural world a specifically surrogating or substituting the role of family pets. This situation could contribute detrimentally to the increasing disaffection with nature, due –partially- to the ubiquity mediation of technology in our relatedness with the natural world.

> There is increasing interest in examining AIBO's potential as a social companion and adjunct to therapy, especially for vulnerable populations. [...] While advocates argue for the advantages of robotic social companions, skeptics (Sparrow, 2002) caution that robotic substitutes may deprive isolated or vulnerable individuals of the benefits of a living animal, such as a therapy dog or pet. (Melson, Kahn, Beck, & Friedman, 2009, 546).

Researchers on HAB are cautious about our fascination of personified technologies that can -to some extend- *undermine* our predisposition to focus on life and lifelike processes –most probably a biologically based need, integral to our development as individuals and as a species.

> Moreover, one cannot rule out the possibility that increasing exposure to mediated interaction with animals, through robotics, virtual reality and other media, may come at the expense of direct engagement with living animals. Whether children will suffer from "nature-deficit disorder" as a result, as Louv (2005) warns, is unclear, but the social consequences, especially for children, of reduced engagement with the natural world should be an urgent focus of study. (Melson, Kahn, Beck, & Friedman, 2009)

What is really paradoxical is that the risk of this subrogation lies on robot's capacity to take advantage of our adaptive proneness to natural world.

Changes in Interpersonal Relatedness

The use of social robots in one-on-one close proximity services do change human-human interactions. These changes may be beneficial as the reported increase in the amount of interpersonal communication (i.e. the robot acts as a social facilitator) or detrimental, interfering or even replacing interpersonal interaction (i.e. the robot become an isolating factor) (D. J. Feil-Seifer & Matarić, 2011).

Robots modified to be more *acceptable* to vulnerable populations, such as the infirm elderly, may then be more easily introduced into facilities as *good enough* substitutes for living beings (Turkle 2012). Thus, a robotic pet can substitute for living animals in a nursing home; a robotic companion can take the place of a human visitor; and a robotic caregiver can perform the functions of a human one. In most cases, the intended human users do not have the opportunity to choose between the robot and its living analogue. (Melson, 2014).

Research Issues in Pediatric Settings

Protecting privacy of patients, families and staff is one of the main concerns that often conflicts with the available techniques to obtain data for analysis (i.e. video record the activity or the facial expressions) from social robots interacting with pediatric patients. One limit would be turn the interaction with the robot into some kind of surveillance, even if this is viewed as licit and accepted or promoted by caregivers. Children continuous close monitoring seems to collide with the right every child has to privacy, and another issue is how to disposal the large amounts of personal data recorded by the robot (Ferreira & Sequeira, n.d.). In addition, a robot is not able to properly distinguish between confidential information (e.g. personal health information) and information that the user permits for release, the robot may create an unintended violation of a user's privacy.

Moreover, the misunderstandings and incorrect conceptions of robot's real capabilities induced by a friendly design and communication may induce children to reveal secrets or behave as if the attributions –friendship, loyalty, trustworthy- were true. In these circumstances, -the potential for user deception- the informed consent is questionable if are based in misconception of the robot's actual role (i.e. patient's continuous video-recording, surveillance, providing personal data to caregivers).

These questions are still open and deserve serious debate and critical perspectives before implementation. In the meanwhile, deploying robots in hospitals require complex trade-offs between effectiveness, safety and fairness that often result in restricting robot's autonomy and even testing the systems under wizard of oz operation (Howard, 2015).

2.6. Thesis' Objectives within the State of the Art

To wrap up the stat of the art chapter, in this section the main gaps and challenges in the field (both substantial and methodological) are summarized along with the intended contributions of the dissertation.

2.6.1. Gaps and Challenges in HRI Research on Companion Robots

The Added Value Issue (approach)

There is still a lack of sounded evidence on the effectiveness and efficacy of robot based interaction practices, compared to other type of intervention. There might be advantages to using robots, but it is advisable to point out clearly the added value and to justify the use of robots compared to interactions with other people (e.g. in care situations), animals (e.gl in therapy scenarios), non-robotic toys (e.g. in play or in educational applications), computers (e.g. in education or entertainment applications), or other biological or artificial entities that might serve a similar function depending on the application domain. Therefore, comparative studies exposing people to robots and to other comparable artifacts can illuminate the added value of a robot, and thus provide a justification for HRI research in this domain that goes beyond scientific curiosity or technological interests (Kerstin Dautenhahn, 2007a, 106).

Companionship Definition and Delimitation (conceptual)

There is no scientifically established knowledge about what makes an agent an acceptable companion (Maklosi LIREC, 2008). From the ethological-functional perspective is highlighted that there have been only few attempts to define the functions of companion robots, it seems inescapable to come up with a functional definition of a companion before such agents are constructed. More importantly, those functions should be formulated in relation to the current state of technology, that is, no more complex function should be targeted than what can be supported reliably by present day technology. (Á. Miklósi & Gácsi, 2012, 2).

Appropriate Techniques to Systematically Asses HRI (methodological)

Due to the relative lack of previous work that one can build on, a lot of experimental and methodological "ground work" needs to be done, such as the development of appropriate analysis and evaluation techniques (K. Dautenhahn & Werry, 2002, 1132) to study the impact or effect of the interaction on users, combining direct and indirect (i.e. self-report) data. In the following illustrative excerpt Matellán (2011) pinpoint the need to find operative and objective definitions of the targeted outcomes of robot's company:

> After three months of cohabitation at home, the study would be successful –from a challenge perspective- if the owner spends more than thirty minutes daily interacting with it, if this were to happen it could mean that the human considers the robot as something more than a simple appliance, another approach would be to request feedback from users, but the answers would be less objective then. (Matellán & Fernández, 2014, 211)

Emotional Impact (conceptual/empirical)

> Anecdotal and empirical evidence suggests that people respond emotionally towards robots. However, systematic investigation on how, when, under what circumstances and to what extent people react emotionally is scarce. (Rosenthal-von der Pütten et al., 2014)

> [...] interactions with robots are still mechanical in nature, and it is unclear to what extent they are able to provide the emotional and social satisfaction that human contact can provide. (Kerstin Dautenhahn, 2007a, 106)

Replicability of Studies and Results' Generalization

According to Miklósi & Gácsi (2012, 6-7) it is more unfortunate that the design and methodological problems of most studies with pet robots do not allow for any strong conclusions to be drawn. Issues to be addressed to build a well sounded amount of knowledge are:

1. Most observations were constrained to a single exposure in spite of the fact that the real utility of such robots would be in the long run. One may expect rapid habituation over time which may compromise the utility of such invention
2. Little effort was taken to control for differences in the form and behavior of the two agents (live dog vs. AIBO) and in most cases the behavior of the AIBO (and the dog) was not reported.
3. Little care was taken to control for differences in familiarity and novelty.
4. The participation of another human in the social interaction may actually "overshadow" the relatively small difference in the social effect between the AIBO and the dog.

One of the most challenging issues in HRI research is that interactive behaviors with robots are extremely platform dependent and HRI community investigate human interaction with diverse platforms with a huge rang of appearances, affordances and competences, that -differently from human-, present substantial differences to each other affecting communication and interaction. In observational studies, this situation implies to build *ad hoc* category systems and coding schemes to register and analyze behavior for every single new platform (or new version). On the other hand, observational analyses hopefully could benefit in the near future from computational vision system developing automatic systems to measure and coding behavior, to overcome the tedious and discouraging time-consuming hand coding of the video data and would be able to automatically recognize relevant behaviors such as facial expressions, gaze, gestures, and movements.

In addition to the variability of social robots under study, research on HRI encompasses a wide range of focus and interests on diverse application domains -education, therapy, entertainment, and home assistance-. In addition, the studies involve diverse users' profiles (e.g. elderly, children with developmental disorders) with relevant differences in key competences for social interaction and performance:

> Due to the specific nature of the application area [–therapeutic-] sample sizes are usually small and heterogeneous with regard to the interactions competencies of the subjects. (K. Dautenhahn & Werry, 2002)

Long-Term Empirical Evidence on Bonding Dynamics

Despite the broad range of published literature, there is a shortage of experimental data about the interaction between humans and robots, particularly in the case of long term interactions to identify behavioral patterns (greetings mechanisms, recognition, help request, etc.) and to stablish how these patterns relate to different user profiles (age, gender, education, etc.) and their cultural influences (countries, religious beliefs, political attitudes, etc.).

From the methodology perspective, researchers face big challenges evaluating systems in the wild, especially with regard to long-term interaction (De Graaf, Allouch, & Van Dijk, 2017). More long-term studies are needed with social robots spending long periods of time interacting (at different levels) with humans. Observe first impressions are important in HRI and probably enough for many applications where human-robot encounters will be brief, and non-repeated (i.e. a museum guide). However, many other applications domains require studies involving repeated, long-term interactions. In particular, the long-term studies would allow to investigate the bond forming dynamics in a pertinent time scale.

> So far, only few long-term studies with virtual and robotic companions have been conducted; most of them relying mainly on subjective data (interviews, questionnaires) or very simple performance measures. (von der Pütten, Krämer, & Eimler, 2011, 327)

Preferences and attitudes are likely to change over time, and novelty effects will wear out, developing user experiences with the robots and gaining use skills might change the user's attitudes towards, uses of or even their conceptualization of the robots, and these changes can only be studied in long-term designs.

Carrying out long-term interaction studies is labor, time, and equipment intensive, but crucial in order to address situations where robots will cohabitate with humans in their homes or workplaces (Kerstin Dautenhahn, 2007a; Matellán & Fernández, 2014). In addition, according to De Graaf (2017), the main reason for this shortage of long-term HRI studies is that robot technologies are generally not robust enough to be studied outside the laboratory for extended periods of time without supervision of an expert.

2.6.2. Dissertation Goals within the State of the Art

1. An integrative revision of the state of the art outlining the current gaps and challenges of social HRI –and in particular in child/pet-robot interaction- and the confluence and interrelatedness of different scientific domains. In the case of the present dissertation we dare consider that the investigation and systematization of literature and antecedents is not just an unavoidable revision of previous work but a contribution in itself, being social HRI an *immature* discipline (Chapter 2).
2. A novel dynamic model of bond forming with pet-robots based on in the field studies and on the available knowledge from the fields of HRI, social psychology, ethology and design (Chapter 3).
3. A data-driven categorization of child-Pleo –a baby dinosaur shaped pet robot-interaction *customizable* to different contexts and platforms, contributing both with new behavioral data on CRI and a methodological tool (coding scheme) for observational studies with children (Chapter 4).
4. A multi-method case study of pet-robot interaction over time in a pediatric hospital, providing evidence-based knowledge on bonding dynamics in the wild and lessons learned on the feasibility and effectiveness of pet-robots' programs to accompany hospitalized children and their families (Chapter 5).

3. A Dynamic Model of Child-Robotic Pet Dyad

In this chapter is presented a novel model of bond forming, integrating antecedent studies and insights from different disciplines, aiming to shed light on children socialness with pet-robots.

This chapter is organized as follows: first, a categorization of the social situation defined by the complementary roles of owner and pet, taking as a referent the human-dog relationship; secondly, a revision of the key features of this system that could be transferred to owner-pet robot relationship; thirdly a dynamic model of bond forming with artificial pets over-time is presented. The chapter ends with a formulation of the key mechanism involved in bond forming with pet robots: their capability to display credible artificial attachment.

3.1. The Owner-Pet Social System

The owner-pet social system is an instance of interspecies relationships (i.e. associations between biological non-conspecific entities) (Kovács et al., 2011). More particularly, owner-pet relationship is an association between humans with a subservient species, based on a core asymmetry: domestic animals cannot survive without human supplies while human do not need the company of animals. Thus, while from the pet's perspective the association with humans is indispensable, from the humans' perspective keeping a pet is a choice and in our urban societies can be considered an act of consumption of a no primary good.

Based on this primary asymmetry, the questions that arise are: Why humans decide to cohabite with animals and commit themselves in taking care engaging -not negligible- emotional and financial resources over-time to satisfy the family animal needs? How do pets manage to get from humans the resources they are not capable to obtain otherwise? In a word: which is the essence of human-pet bonding? Kaplan (2005) considers that the essence of human-pet association is pets' deployment of an irresistible combination of freedom and attachment:

> How is this bond with the animal expressed in the daily life? Let us observe a dog going for a stroll. It walks sometimes before its master, sometimes behind. Sometimes it goes around to explore but keeping an eye to check if its master is always there. The maximum distance the dog refuses to overstep summarizes clearly the two opposite tendencies that constitute the richness of its behavior: its freedom and its attachment. Freedom and attachment are the two essential components to explain our rapport to these animals. What we really appreciate is that the animal is attached to us, this is to say that it shows to us a unique behavior different from other behaviors the dog reserves to anyone else. Nevertheless, this attachment is valuable just because the animal is not forced to be attached as long as it is a free and autonomous creature. (Frédéric Kaplan, 2005,74)

> Is the capability of autonomy and attachment that distinguishes the domestic animals from performing objects and from wild animals. (Frédéric Kaplan, 2005,75)

> … the value we give to the bond with the pet is related to our belief that the animal may bond with us but it is not forced to. This situation allows us to imagine a reciprocal link. In the same way we devote time taking care, the pet renounces a part of its autonomy in return and keeps attached to us. Several authors have insisted in considering this capability of reciprocity as the crux of the difference between animals and traditional machines. (Frédéric Kaplan, 2005,75)

Therefore, human relationship with pets is determined by the interdependent roles of master (i.e. owner or keeper) and animal defined by three features: hierarchy, uniqueness and bi-directional connectedness. Hierarchy relies on the primary dependability that defines the subservient role of the animal expressed through obedience and submission. Uniqueness invests the owner as master among other humans. Connectedness is based on attachment by the side of the animal and on a combination of obligation and emotional involvement by the side of owner (Kovács et al., 2011).

As stated above, from the pets' perspective, these features serve the critical function of obtaining the resources for survival in an epimeletic and et-epimeletic interactive behavior, from which animals satisfy their basic needs, while humans obtain social warmness that seems to be the core functionality of family animals in our societies.

Dog-owner relationship is considered the prototype model of owner-pet social system to *map* pet-robotic social behavior. Nevertheless, inspiration may be gained also from other human-animal interactions like with cats or horses, though they lack the generality and wide scale of human-dog interaction (Á. Miklósi & Gácsi, 2012, 8). In the present work our reference is always dogs, unless it is specified otherwise.

3.1.1. Pet's Social Behavior for Bonding

Pets' social affiliative behaviors fit specifically well in the human social world and are the base of the lasting relationships with dogs and of the *success of human-dog cohabitation* (Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014; Miklósi, 2008; Miklósi & Gácsi, 2012)The most important human-directed skills of dogs are the attachment behavior, the capability to receive and send communicative signals, the rule learning and following, and the ability to understand and predict human intentions (Miklósi, 2008).

These attachment related behaviors seem to elicit in turn an emotional response in the human counterpart (i.e. concern) that is the essential drive to engage in care giving activities (i.e.

obligations) that go beyond the immediate reward. We can identify a pseudo-parental orientation to satisfy pets' needs that explains better the owner–pet relationship than other utilitarian effort/reward mechanisms.

In addition, pet's playful behavior supports gratifying interaction -the other pillar for lasting association- that is based more on what the animal does (i.e. funny explorative and playful behavior, teaching-learning episodes) rather than on what the animal means in terms of a dependable member of the family community.

Table 3-1 Functions, mechanisms and social skills supporting human-dog lasting association (Author)

Functions	Role-dependent attributions	Mechanisms	Behaviors	Social skills	Resources
Satisfy the need to belonging	Hierarchy /Dependency	Emotional alignment	Greeting	Recognizing	Orientation
		Unique affiliation	Attention seeking / giving	Readable Expressiveness	Gaze behavior
	Individualized Attachment	Engaging communication	Proximity seeking	Responsiveness and contingency	Tactile/Auditory/ Visual sensing
		Rewarding reciprocal interaction	Resources soliciting	Monitoring and low monitoring	
Entertain beyond novelty effect	Enjoyable interaction	Exciting curiosity over time	Affectionate interchanges		
		Learning	Joint attention		
		Growth (evolution)	Play		
			Obedience		

Both motivations –nurturing and play- can be unevenly distributed between the members of a family being for instance children who more exploit the playful disposition of pets to engage in enjoyable interactions while parents fulfil the obligations related to satisfy their biological needs. Either care-giving or play can be rewarding depending on individual variables such as age, altruistic-selfish dispositions, expectations, attitudes towards animals and previous experience (Barco Martelo, 2017).

Organizing mechanisms supporting the human-dog relationship include attention giving and getting, greeting, proximity seeking, resources soliciting, human monitoring and low monitoring, non-verbal communication such as gaze and touch, including shared attention (Policastro et al 2009 in Dahl, 2014), individual recognition and emotions alignment (Dahl, 2014; Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014; Miklósi, 2008). All these mechanisms and social skills (see Table 3-1) serve to form the essence of dog-human association: the *individualized attachment* with the owner. (Á. Miklósi & Gácsi, 2012, 7,145)

3.1.2. Specificity of Children-Pets Relationships

The *biophilia hypothesis* (Kellert & Wilson, 1993) contends that there is an evolutionary-based innate predisposition among children to attend to living things, including but not limited to animals. The fascination with animals does not have to be taught; children seemed primed to respond with feeling, whether attraction, fascination, fear or disgust. The child–pet relationship has been termed a *flexible alliance* take many forms and may fulfill some of the important developmental functions that one sees in human–human relationships, fulfill needs to nurture and be cared for, to support and derive support from, to play with, to secure companionship, to feel secure, among others (Melson & Fine, 2010, 190).

Beneficial effects of relatedness with animals on children development and wellbeing has been recurrently reported:

> Scholars have considered theory and research on the possible role of animals in children's lives: (1) nurturance and caring for others, including empathy; (2) coping with stress; (3) emotion regulation, self-control and positive adjustment; (4) reduction of maladaptive outcomes, such as conduct disorder symptoms; (5) theory of mind; (6) social support; and (7) physical activity, among other outcomes. Parents cite increased responsibility, companionship, and "fun" as benefits that companion animals confer on their children. (Melson & Fine, 2010, 181)

3.2. Bond Forming with Robotic-Pets

In this section a model of bond with robotic-pets dynamics is presented. We prefer the term *bond* to designate the humans' affective rapport with a pet, rather than *tie* that emphasizes other dimensions of the human-animal association such as duty, obligation or responsibility.

The model presented highlights the social dimension of bonding with a robot. Our assumption is that the social rapport and –eventual- bond with the robot emerge within a specific social context that influences decisively this process –as any process in children's lives-. Similarly to children relationships with real pets, children-pet robot interactions are embedded in multiple contexts, such as family, school, neighborhood, community, and culture, influencing the quality of the child–pet contact and relationship (Melson & Fine, 2010, 190).

Giusti (2006) highlights as well the importance of the specific context within which the interaction with pet-robots is played:

> *[Our preliminary study seems to show that]* the creation of significance and interpretation during the interaction depends on not just the machine's physical and functional characteristics but also, and mostly, the specific context of interaction, on the personal history that every interlocutor calls into play and on the perception of mutual affordances, some of which come from the stimulus given by touching, hearing, seeing and moving, others from psychological processes that mediate empathic response. (Giusti & Marti, 2006)

From our behavioral approach, we consider that children relatedness to pet-robots is instantiated within and through the interaction in a dynamics of shaping and reshaping its significance and value over time (Pitsch & Koch, 2010). Though focused on the interactive surface, the context within which this interaction unfolds is prominent in our model, differently from other micro-social approaches to child-robot interaction.

3.2.1. Developmental Model of Child-Pet-Robot Bonding

The model introduced in this section takes insight from i) Senge's bio inspired model of organizational change where growth and limiting processes compose a lively *dance* (Senge, 2000), ii) Kaplan's model of our changing experience with everyday objects over time according to different value profiles (Kaplan, 2005), iii) the *Domestic Robot Ecology* framework (DRE) that organizes the knowledge on domestic robots adoption at homes (Fink, Bauwens, Kaplan, & Dillenbourg, 2013; J. Y. Sung, Grinter, & Christensen, 2010), iv) Human Animal Bonding (particularly with dogs); and v) the model of children play that puts in the spotlight the social dimension of children's behavior (Steenbeek & van Geert, 2005, 1).

More indirectly, some insights are drawn from the general models on close and enduring relationship between humans (see section *2.1.3.1. Interpersonal models*), like Levinger's five-stage development model of relationships, that has already been applied to gain understanding of human-robot relationships (Barco Martelo, 2017). Our model draw insight as well of other models of close relationships dynamics like Kelley's (Kelley et al., 1983) and Rusbult's investment model based on commitment and satisfaction, explaining romantic associations dynamics (Rusbult & Van Lange, 2003). Importantly, these models address the same two main questions than our model in the situation of child-pet robot relationship: how to distinguish among relationships differing in closeness at any single point in time, and how relationships change over either a short or a long time span.

Therefore, we base our model of children bonding with pet robots from the following disciplines, according to the multifaceted essence of these creatures: i) product *design* –a pet-robot as an everyday object (Jacobsson, n.d., 2009; F Kaplan, 2005; Ljungblad, Kotrbova, Jacobsson, Cramer, & Niechwiadowicz, 2009), ii) human-animal bond –a pet-robot as a pet (Melson & Fine, 2010; Miklósi, 2009; Myers, 2007), iii) change management- bonding as a dynamic process to be managed, and iv) technology adoption and appropriation.-a pet-robot as an innovative device (Castro González, 2012).

Most surprisingly, both designers and ethologists address the same questions when wondering about objects, robots or pets' *adoption*: Why a particular entity is allowed to cohabit with us? How can an object or an animal find a "niche" in our lives over time? What motivates an individual to keep long-term interest in non-human entities?

We consider that all these inspiring models share the same essential assumptions:

- Use and adoption are social processes that unfold over time through specific stages.
- These stages feature recognizable patterns on use, interaction, perceptions and affect.
- The process faces specific challenges and factors that facilitate or hamper adoption.
- The process towards adoption can be managed through design and/or through intervention.

Our model borrows from Senge the system diagrams (Fig. 3-2), a way to illustrate and sketch out complex interrelationships between processes that are difficult to describe in words, organizing insightfully and intuitively its complexity and dynamics. We also draw from Senge the perspective of management: the process of initiating and sustaining change –a new relationship in our case- has not only to be understood but also managed. According to Senge's work, along with enhancing the forces sustaining *momentum* (i.e. the impetus forward), it is most important understanding those forces that impede progress. In the case of pet-robots, bond forming and adoption face some challenges that typically occur at different stages as a natural part of the process. Therefore, to every challenge corresponds a suitable strategy -effective actions based on the previous knowledge and the consideration of the whole process. Thus, to succeed in sustaining the process it is necessary to recognize, anticipate and then manage these challenges.

Kaplan, as a designer, wonders about function: why particular objects manage to stay in our homes and become our everyday objects? To answer this question, he proposes an explicative model based on the *value profiles* of objects. Value profiles "are meant to capture in a single hypothetical curve the evolution of the experienced value of an object" over time. These changes of the experienced value of daily life objects unfold through three stages: immediate value (the first minutes of interaction with the object, that are enough to be excited or disappointed), short term interaction (lasting over a month) and long-term interaction in a range of many months or even years (Kaplan, 2005).

Following this model, objects conform into four different types according to the evolution of their experience values: objects *type a)* with high immediate value followed by a progressive drop (e.g. fashionable clothes), objects *type b)* where experienced value increases slowly because the necessary training and adaptation, reaches a peek when the users master the technology and slowly becomes obsolete with new technological progresses (e.g. computers), objects *type c)* reach their optimum almost immediately as almost no training is required and stay at that level with very small risks of obsolescence or lassitude (e.g. corkscrews), and objects *type d)* where the experienced value keeps increasing over time (e.g. notebook).

This value profiles has been attributed through a data driven process based on features of 40 everyday objects to seven specific features that different types of entities –living or artificial-possess in different combinations. This features are versatility, social orientation, network factor, investment, historical capacity, personalization and control. Kaplan's bid is that this knowledge can be used to design objects with specific combinations of these features to obtain the desired experience value profile. As a consequence, Kaplan concludes that provided that the very essence of a *companion* robot is to remain valuable -engaging our interest and dedication-over extended periods of time, they should necessarily be objects of class d), their value increasing over time, what, according to Kaplan' taxonomy, corresponds to objects with high historical capacity, versatile functionality and orientation towards social interaction.

> Could we design robots that would lead to experiences enjoyable after a few minutes, more valuable after a few days and even richer after a few months? If such a machine could be designed, it would certainly find its place among long-term everyday objects. But this is a challenging aim as evaluation criteria are different at every timescale. (Kaplan, 2005, 62)

To sum up, following Kaplan's model, a companion robot should be catchy at immediate impression, meet or exceed our expectancies in the short time and keep increasing its value in the long-run. However, the insightful and lucid we find Kaplan's model to identify design properties relevant to sustainable interaction with robots, from our perspective the underestimation of the emotional and social dimensions of the experienced value do not capture the complexity of children's bond forming. On the other hand, Senge's model provides a complementary focus on the psycho-social level and a key role of the emotional experience of perceived threatens and rewards as the main force impelling change.

Inspired by these two perspectives –focus on design and focus on management - the proposed model regards the social bonding with companion robots as a complex multi determined process, similar to a plant growth where the potentiality existing in the seed results in an actual development according to environmental conditions that are dynamic and changeable as well (Senge, 2000) (Fig. 3-2). From this integrative perspective, the features of the robot's embodiment and behavior have to be carefully designed to enhance its intrinsic appeal while situational variables have to be managed along the process to expand robot's potentiality and thus maximize the experienced value.

We assume that the experienced value of a pet-robot from children's perspective lies on the subjective experience of rewarding closeness that provides both warmness and enjoyment. There is no optimal value for this closeness as long as each child may find he/herself comfortable in any of the stages towards intimacy or even declining or avoiding any close contact with the robot. Eventually, this feeling of closeness can change into attachment to the robot what would not always be advisable or healthy. However, in the framework of this work we consider that getting emotionally closer to the pet-robot is desirable for the effectiveness of a pet-robot based intervention. Closeness brings an added value to interaction that –from our theoretical model- opens a new space for pretend play that can bring beneficial effects for children (e.g. alleviating loneliness, giving comfort) that other kind of relatedness with the robot could not provide (e.g. distract).

Another insightful empirical-based model on acceptance and refusal of pet-robots is De Graaft's *negative* approach of no-use (De Graaf et al., 2017). Drawing from a longitudinal study in the real world where the rabbit-like Karotz –in previous versions called Nazbatag- was introduced in 70 people's own homes for a period of six months the author collected reasons for refusal and abandonment through questionnaires and interviews. The model proposes three different users (non-users) profiles according to the moment and the reasons why participants refuse or abandon the use of the pet-robot: resisters, rejecters and discontinuers. Resisters are those people who never used a technology because they do not want to, rejecters are those people who have voluntarily stopped the use of a technology before an actual adoption, and finally discontinuers are those who decide to stop using a technology after previous initial adoption. Acceptance factors and motives for non-use are measured and analyzed providing a useful map of challenges in personal domestic robots long-term use.

3.2.2. Stages, Challenges and Strategies in Bonding Enhancing

The model proposes three stages in bond forming: *first impression*, *engaging in interaction* and *relatedness*. Each stage is defined by specific *challenges* –due to the limiting process at micro, meso and organizational levels- and by the associated *strategies* to impulse the relationship into the next stage (Fig. 3-2).

This explicative model for child bonding with pet-robots aims to be general and applicable to the relationship with any type of robotic pet. However, the more insightful studies on children and families bonding with robots over time involve three popular robotic pets: Pleo robot, a cartooned bio-inspired baby dinosaur, the dog-robot AIBO, a mechanize puppy and Karotz, the rabbit-like little robot (see Fig. 3-1; Table 4-4 for a summary of a selection of pet robots' main features, and Section *4.2. Robotic pet Pleo* for a detailed description of the robot). Our main sources are the Fernaeus', Jacobsson's and Pitsch's studies with Pleo (Fernaeus et al., 2010; Jacobsson, 2009; Pitsch & Koch, 2010), Kaplan's analyses of people relatedness with AIBO (F Kaplan, 2005) and De Graaf longitudinal study of non-use with Karotz (De Graaf et al., 2017) (see Table 2-3 for further information about these studies).

a) b) c)

Figure 3-1 Robotic Pets
a) Pleo[19] b) AIBO[20] c) Karo

3.2.2.1. First Impression and Immediate Interaction

First impression is a unique and unrepeatable situation in the flow of the experience of interacting with the robot. Is the precise moment when, without any previous experience with

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[19] http://www.robotshop.com/uk/pleo-rb-autonomous-robot-life-form.html
[20] https://www.robotcenter.co.uk/products/aibo

this particular robot, the robot is presented to the child for the first time. In other words is the moment when the child is *exposed* to the robot's presence for the first time. If the child engages in interactive behavior with the robot there is a transition to the next stage *short-term interaction*; if not the process is finished.

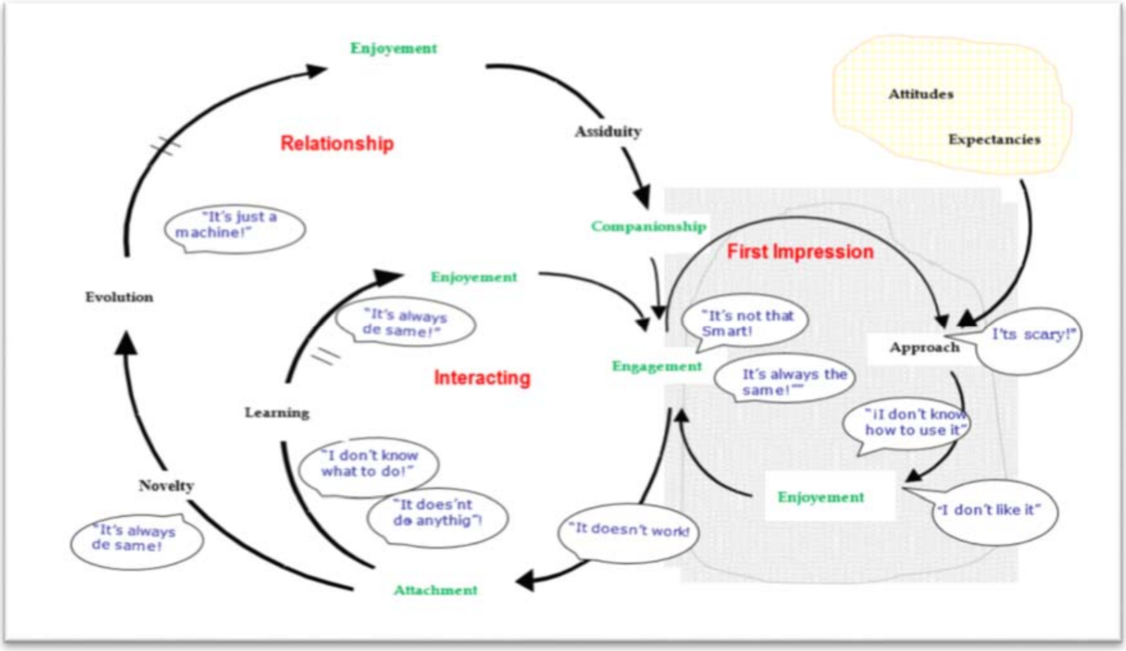

Figure 3-2 Dynamics of bond forming between children and pet-robot
(Source: Author inspired in Senge's diagrams representing organizational change (2000)
The three loops represent the three stages on bonding. In green effects on user. Inside the balloons expressions representing users' challenges.

The main factors influencing the impression -immediate value- and children initial behavior are: individual variables (i.e. age, gender, attitude towards animals and towards technology, familiarity with robots), robot's appearance (e.g. humanoid, pet, fancy creature), expectations, the situation (i.e. social situation and the physical scenario) and the way the robot is introduced or presented to the child (i.e. like a toy, like an animal, turned on or off, with a name).

With robots –as with any object- appearance matters (Sciutti, Rea, & Sandini, 2014) and in a few minutes any user will have made his or her first opinion about them (Kaplan, 2005, p.4). There is a consensus in the field that robot's appearance has a major influence on the assumptions people form about applications and functionalities and about robot's *social competences* (i.e. robots' capabilities) (Díaz et al., 2011; Fernaeus et al., 2010; Jacobsson, 2009; Paepcke & Takayama, 2010; Sciutti et al., 2014).

Based on the appearance of a robot, users generate expectations about its abilities (e.g. if a robot features a camera that resembles an eye one will expect the robot can see). The interaction will only be enjoyable if the actual functionality matches or exceeds expected functionality (Kaplan, 2005). That is why robots' design should convey clear message about the type and context of usage of the robot, and more importantly, it should trigger the right kind of expectancies (Kaplan, 2005, 4; Lohse, 2010,48).

Following Lohse (2010, 29) we want to highlight the importance of expectancies in the first encounter with a robot. Expectancies are

> ...beliefs about a future state of affairs, subjective estimates of the likelihood of future events ranging from merely possible to virtually certain. […] The expectancy is where past and future meet to drive present behavior. (Roese & Sherman, 2007, 91)

The formation of the expectations about the robot is primed first of all by communication from other people before the actual encounter. Besides communication from other people (indirect experience), Olson, Roese and Zanna (1996) name two more sources of expectations: direct personal experience and beliefs that are inferred from other beliefs. Every expectation is based on at least one of these sources, all of which can be biased (Darley &Fazio, 1980 cited in Lohse, 2010) and most importantly from our perspective, *influenced* (i.e. through design) and *managed* (i.e. providing information or prompts). This process of building expectancies usually happens before the interaction starts -before meeting or pre-adoption phase- (Fink et al., 20 13; J. Y. Sung et al., 2010) and influences how it will develop.

The challenge in this first stage is to appeal children and attract them to interaction, and avoid children's responses of wariness or reluctance. In general, pet robots are catchy from children's perspective, evidenced by the observations in the field:

> Nearly all participants were indeed fascinated by the way Pleo reacts to touch, and praised how its detailed movement pattern looks very "real". (Fernaeus et al., 2010)

On the other hand, though the response to robot-pets life-likeness is amazing, Kaplan wonders whether this first impression really produces a higher immediate experienced value or on the contrary introduces the machine in a misleading way (F Kaplan, 2005, 62). In addition, life essences attributions (i.e. drives and intend) do not always result in approach and positive attitude. In fact, according to Pitsch the most frequent response experiencing Pleo as an animate object in young children is wariness because of its sudden movements and sounds (Pitsch & Koch, 2010).

To sum up, at the first impression, the robot has to be compelling through an attractive design and behavior (i.e. novelty effect), has to look nice and harmless; create exciting but realistic expectations, excite curiosity, provoke overpowering wonder, surprise and amazement and emotional appeal. Moreover, robot's affordances have to provide the key of a successful and enjoyable intuitive interaction not only with children but with their social environment.

> Infants 10 years old have been regularly found to engage in some form of experimental test of the behavior of the robot while adults were less keen to spontaneously interact with the robot, skipping this experimental phase to directly make comments about what their impressions about the machine. (F Kaplan, 2005)

The desirable outcomes at this stage are robot's acceptance and the willingness to keep interacting. Users that reject the robot at this moment are according to De Graaf classification rejecters, those who actively refuse the use of a technology before an actual adoption (De Graaf et al., 2017).

3.2.2.2. Short-Term Interaction

Interaction occurs in the first encounter and in the subsequent encounters –if any- between the child and the robotic-pet and may greatly differ from immediate impression. It necessarily comes after the first impression stage but it is not necessarily followed by the sustained usage stage. Each episode of interaction increases or decreases the probability to progress forward adoption. This second phase after initial exposures is when people decide between adopting and continuing or rejecting and discontinuing the use of a technology

The main features of this stage are that i) the robot is evaluated in the first days according to expectations and affordances, ii) robot's capabilities and limitations are learned (Fink et al., 2013; J. Y. Sung et al., 2010), iii) interactional patterns with the robot are developed (Pitsch & Koch, 2010) and, eventually iv) affective behaviors appear or consolidate.

Evaluating against expectancies

Robot's actual usage is compared with expected functionality or utility (Kaplan, 2005) and -as the studies on long-term interaction pinpoint- the main risk is disappointment or *disenchantment* (De Graaf et al., 2017) when the –high- expectations participants initially had are not met. In general, interaction with any object is enjoyable when actual function matches or is superior to expected functionality. But in the case of pet-robots the expectancy may be huge: the illusion of experience Pleo as an alternative to a live "pet" (Fernaeus et al., 2010). All the families observed spontaneously made comparisons between Pleo and a pet animal because Pleo belongs to a category of commercial products that are broadly been spoken as electronic pets and one of this major selling points has been its capability to develop into a more complex and responsive entity with time, like a living being (F Kaplan, 2005).

Table 3-2 Coding Scheme of reasons for no-use
(Source De Graaf, Allouch, & Van Dijk, 2017)

Code	Definition
Disenchantment	A state of disappointment or disillusion regarding (the use of) the robot.
End of novelty	Losing the earlier increased interest in the robot
Lack of motivation	Lacking a driving force to use the robot.
Need not satisfied	Being displeased or feeling discontent with a sought need the robot should fulfill.
Reliance on others	The act of or the perceived need to rely on others to be able to (properly) use the robot.
Replaced by other device	The replacement of applications or the complete use of the robot with another device.
Restrictions and problems	Foreseeing or experiencing barriers to use the robot.

Cultural and societal expectancies on robotics are higher than more mundane technology in a mixture of misleading beliefs and naïve fantasies. In particular, in the case of Pleo, the lack of active and explicit activity seems overshadows the more subtle form of interaction that Pleo do in fact perform (Fernaeus et al., 2010). Expectancies not met, according to previous long-term studies on Pleo *adoption*, are Pleo walking and attending to objects and sounds, the level of intelligence and computational features, as well as the level of basic technical robustness.

The challenge in this stage is sustaining *momentum* and keeping children engaged and interested when the novelty effect is worn off.

> ... a frequently occurring phenomenon in the interaction of humans with machines is that people are initially interested in interacting with an artificial entity; but are, however, quickly bored or annoyed with it, refuse to use it again and even show aggression towards the system. (von der Pütten, Krämer, & Eimler, 2011, 327)

In particular, Kaplan (F Kaplan, 2005) suggests the following strategies –from design and communication- to avoid disappointment and to lead to a positive short-term experience::

- The design should convey clear message about the type and context of use of the robot, triggering the right kind of expectancies

- The communication (i.e. publicity, instructions, affordances) should be realistic and do not induce overestimations of the robot's real competencies (e.g. speech understanding) that lead to disappointing experiences
- Robots should be transparent providing maximum information about what they can and cannot do

On the other hand, Dautenhahn recommends to draw lessons particularly from situations where people do not treat robots socially, to unveil the aspects of a robots' appearance and behavior that might *break the illusion* and how to recover from such situations (Kerstin Dautenhahn, 2007a).

Development of Interactional Skills

This is the phase of acquiring the social skills to interact smoothly and satisfactory with the pet-robots, getting to know their limits and capabilities, exploring its potentiality, guessing rules and mechanisms, identifying social and technological patterns (i.e. Pleo's favorite food, how AIBO track the pink ball), understanding cause-effect relationships and pushing the robot's *limits* both physical and *psychological* (F Kaplan, 2005). Engagement and enjoyment are reinforced when the dyad succeeds in a contingent interaction related with the basic functions of the owner-pet situation, what Pitsch names the interactional responsive conduct as "attempts to stablish contingent interaction with the system" (Pitsch & Koch, 2010).

Sometimes the interaction is too difficult and effortful to get the intended social interchange with the robot, when to master how to use the robot is perceived as too difficult or effortful. These *restrictions and problems* (foreseen or experienced barriers to use) are reported by De Graaf as the second reason why (after *disenchantment*) participants gave up using the robot in this phase of the adoption process (De Graaf et al., 2017).

Affective Involvement

In the affective dimension, typical observed behaviors that appear in this stage are individualization, personalization and bonding, such us giving nicknames, creating a special place, assigning things for it and bringing to show to friends and colleagues. A particularly common practice is personalization through accessorizing adorning the pet with different items (Jacobsson, 2009).

> Very commonly the "owner" decides gender and choose a name (in some cases gender simply follows from picking the name) what are frequently important and particularly joyful episodes

> maybe related to our culture naming is an important piece of a larger process including individualization, bonding and family integration (Jacobsson, 2009).

This affective involvement expresses in behaviors of taking care of the pet's needs and giving affection such as petting and touching and talking to. Social rapport can manifest as well in substantial (i.e. body to body) contact as carrying in arms, reassuring, cuddling, stroking, hugging, pressing to bosom, making it sleep.. (Fernaeus et al., 2010) This process of individualization and emotional involvement could lead to dilemmas when Pleo has to be replaced if breaks down or malfunctioning because people feel attached to the particular Pleo and prefer not to be replaced (Jacobsson, 2009).

Ecological Compatibility

In the long-run, the pet-robots' chance to be adopted lies on being compatible with the environment -Fernaeus reported a family that quit the study because Pleo disturbed their dog- fitting the existing eco-systems of toys and resources in the homes grounding on existing play practices and in the context of the use (Fernaeus et al., 2010).

On the other hand, pet robots –and Pleo in particular- seems to require a great deal of care as a part of the relationship, while maintenance issues like skin deterioration (i.e. smell and the paint on the back wears because of the petting) and degradation in general begins to appear (Jacobsson, 2009). Users unavoidably are required to engage in maintenance activities as prepare, update and recharge. A main challenge to bridge the gap between play and maintenance is to make maintenance's tasks accessible for children and integrated in the regular interaction (Fernaeus et al., 2010). While the maintenance of a real pet is part of the interaction and other appliances act *needy* in order to call for maintenance or care (e.g. *Tagamochi*, Roomba), pet robots like Pleo simply stop working, and generally requires the adults' intervention.

In this phase Pleo is experienced as well as a resource for social engagement (Jacobsson, 2009) and some users join in informal communities of friends owning similar toys (Fernaeus et al., 2010).

The strategies in this phase are: supporting the natural proneness to individualization and personalization that reinforces the attachment and the liking, exciting the technological curiosity once the wonder of the novelty effect has faded away, promote occasions for including the robot in play and fantasy games engaging new participants (collaborative game).

The desirable outcome of this phase that leads to lasting relationship are adoption in terms of routine practice and, eventually, bonding (emotional rapport). Users that gave up the robot during this initial period of short-term interaction are, according to De Graaf classification *discontinuers*, those users who decide to stop using a technology after previous initial adoption (De Graaf et al., 2017).

3.2.2.3. Use and Retention and/or Relationship

This stage is defined by the manifestation of affective closeness and the adoption of the robot as a daily life object. Typically participants do not interact with Pleo in the regular manner as in the beginning, and the pet-robots may be ignored and not used at all, except for special occasions such as when friends visited (Fernaeus et al., 2010).

> Getting people to engage with conversational interactive systems is easy –even though interaction often is disappointing, boring or completely irritating-but keeping them engaged over time is a hard task. (Krämer, Eimler, von der Pütten, & Payr, 2011)

> ... even if much more research needs to be conducted on short-term experiences, we believe the crucial issue lie in the capacity of robots to sustain rewarding long-term interactions. (F Kaplan, 2005, 63)

There is not a general agreement in HRI literature about the minimum duration or how many interactions define a relationship as a long-term relationship. Opinions range from 5 weeks (Karapanos, Zimmerman, Forlizzi, & Martens, 2009) to 2 months as the minimum required in a long-term study that aims at observing ordinary use beyond the *novelty effect* (Fernaeus et al., 2010; J. Sung, Christensen, & Grinter, n.d.). In his study (Tanaka & Kimura, 2009) defined a long-term interaction as 45 days in contact with the robot during 5 months. Matellán considers that a valid study on long-term interaction could be about 3 months (Matellán & Fernández 2014, 211). In this model we avoid to delimit relationship in terms of time and consider that long-term starts when sustained use is achieved, which is after the novelty effect wears of and familiarization starts. Some studies report an end of the novelty effect around two months of use –depending the technology-, but is most likely related to behavioral change and the intensity and frequency of use behavior (De Graaf et al., 2017).

> Our participants did in several ways treat Pleo as if it were a real animal (e.g. petting it, giving it names, and displaying emotions towards it). Our study showed that these activities do not seem to be enough to keep a long-term interest. Instead, Pleo was generally treated as a toy, which implied that the children who did play with it did so only for short periods of time and then put it among their other toys. Pleo failed to encourage the regular interaction that is assured by the price and sophistication of this robot, as well as by the concept of interactive companions, as

> promoted by some strands of robotic research. This insides lead to the question of what actually could build up a long-term interest in an interaction with these kinds of robotic artefacts. (Fernaeus et al., 2010)

The challenge is to establish self-reinforcing dynamics to sustain long-term interaction (i.e. training) and to *expand* Pleo's capability to provide engaging experiences exploiting social facilitation and gamification. In the long-term study with Karotz the main two reasons of giving up the use of the robot -after the process of initial adoption- reported by the *discontinuers* were the robot's lack of adaptability and its lack of enhanced sociability (i.e. richer social interaction; initiative in communication).

The strategies to enhance bonding and prevent discontinuity in use after adoption, can be summarized into two factors: autonomous development and learning, and extended *gameability*.

Autonomous Development and Learning

Change and novelty is the essence of attraction and is something that evolving creatures –being natural or artificial- can provide in a self-reinforcing iteration: the more the user interacts with their robot, the more the robot's behavior changes, leading through a positive feedback loop of continuously renewed forms of interacting with the robot.

> One very effective way of performing such a pressure on the user is to link the maturation of the creatures in some manner with the way the user is taking care of his pet. Most of the existing virtual or physical pets have a predefined maturation program which can be slowed down by a lack of interactions from the user. If you don't play enough with AIBO, it will not mature properly in the long run.
>
> The trick is to create a positive feedback loop on the user investment in taking care of the pet. The more the user has spent time interacting with the pet the more it is crucial for him that the pet does not die or run away and matures properly. The initial investment may simply rely on the money spent to buy the pet. Then, the "relationship" emerges from this self-reinforcing dynamic. (Kaplan, 2001)

Immersive Pretend Game

According to Kaplan's model (F Kaplan, 2005) versatility is one of the requirements of objects to remain in our lives keeping increasing interest. The pet robot can be understood –and played- in many different ways including pet-robot as a robot, pet-robot as a social mediator, pet-robot as an object of tinkering and pet-robot as an artificial life form.

Users spontaneously engage in imagination play interpreting robot behavior, attributing meaning to events, utterances and movements, inferring moods, affective states and intent. The naturalness and credibility of emotional expressions support these attempts and guesses that relies on the essence of life-likeness, conceptualizing the robot as an intentional agent whose behavior is influenced by states, beliefs, desires, role, genre and learning capabilities (Díaz M, Saez-Pons J, Nuño N, 2010).

> […] all the present, Pleo included, are contributing to some extend with a more prominent or discreet to this drama, to unfold the progressing story. These owners of robots appear to advance and enrich their experience. We can also see how users are able to actively cope with difficulties (e.g. broken leg) by staging, playing and performing to their best abilities.
>
> [...] meaning can change with context and emerging scenarios would seldom correspond to the ecological niche it was initially designed and tested for. We also see that different locations and contexts characterize very different scenes and scenarios. (Jacobsson, 2009)

Playing –or living- with Pleo may result in social collaborative pretend play that admits a lot of participants playing different roles, according to preferences, inventing new scenarios and dramas with one or more Pleos, that, in addition, have the capability to communicate between them.

Pervasive Pleo

Another way to expand Pleo is providing it with *ubiquity* to complement the physical anchoring being located in different devices –such as smartphones or tablets-, in a process of *teleportation* or *metamorphosis* (F. Larriba, C. Raya, C. Angulo, J. Albo-Canals, M. Díaz, 2015). Robots like Pleo often fail to engage users for extended periods of time, especially when compared to the enormous success of virtual pets in video game consoles or online. Taking inspiration from pervasive gaming technology -where gaming experiences benefit from a mixture of real and virtual game elements, Dimas (Dimas et al., 2010) proposed to extend Pleo's identity in multiple interfaces –*pervasive Pleo*- creating a virtual representation of the robot in a mobile device, providing a supplementary modality of interaction. The mobile device attempts to overcome some of the limitations of the robot, such as battery lifetime and the lack of communication with the user/player, which makes it difficult to interpret the robot's internal state.

Support Tinkering

The robot should meet some users' expectations about *tinkering* as others robotic toys and play kits empowering the user not only to play with them as they are, but also to access and modify their behaviors on a more technical level satisfying the users' technical curiosity and motivation to create and recreate (Fernaeus et al., 2010).

3.3. Artificial Attachment: the Tie that Binds

Consequently with the model proposed above, and the empirical evidence gathered in previous studies, we cannot agree more with Kaplan's when states categorically that to achieve the goal of establishing rewarding relationships with their owner robots must display artificial attachment. In our model is the motor that supports the loop of attraction, interaction and rewarding experiences necessary to sustain the desire to be close.

We know from empirical data that robotic pet's attachment display is compelling. Wonder is a strong emotion that keeps us connected both through curiosity –that drives inquisitiveness and eventually exploration- and through a touching experience –to be touched is commonly a tremendous powerful reward in itself and the base of affiliative disposal. Any of these drives and any combinations of the two are the source of the willingness to keep close and connected to the robot.

Attachment expresses typically through contact seeking behaviors, affection giving, grief and mourning in response to loss, proximity seeking and reunion greeting behavior after separation (Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014; Kovács et al., 2011). These behaviors are well defined and measured by the *Strange Situation* procedure devised by Ainsworth to test the quality of an infant's attachment to his mother or main care giver (Ainsworth et al., 1978) that has been adapted to measure dogs' attachment as well (Topál, Miklósi, Csányi, & Dóka, 1998) and finally, has claimed to be applicable to measure the *naturalness* of the displayed affiliative behavior of a pet-robot (F Kaplan, 2001), as a sort of social Turing test.

Following this rational, if one robot is able to perform the typical behavior of healthy attachment observed in infants and dogs -missing after separation, greets when they are back and continue this normal activities after the reunion-, we would admit that from an external point of view, the robot seems to be attached to its owner. As Kaplan says, the gold standard for an artificial successful pet would be a perfect balance between freedom (that account for internal drives and desires) and attachment (the liking and affiliative motivation to owner's closeness).

In this section, as a wrap up of Chapter 3 we summarize the traits and basic skills required to display attachment behaviors as the crux of the matrix to engage children in lasting self-reinforcing activities that are the essence of the child-pet robot bond. According to Kaplan,

(2001) there are some design principles responsible for the success of existing artificial pets that are necessary -but not sufficient- to ground successful lasting relationships that are uselessness, freedom, dependency, juvenile traits and emotional exchanges.

From the point of view of behavior, the core capability is to present contingent and individualized responsiveness that requires the following mechanisms: social awareness, individualization, contingency, credibility and autonomy.

Social Awareness

To be socially aware a robot should be able to monitor and notice the movements and activity of the users, orient towards them when they change position and stop orienting if they do no initiate interaction (to facilitate synchronization). Moreover, this social monitoring could be implemented also on robots lacking facial expressions by adjusting the speed of approach and the time spent in proximity during greeting and applying a simple mechanical signaler for showing basic emotions similarly to dogs' ears or tail, which movements are interpreted by humans as emotional signals (Faragó, T., Miklósi, Á., Korcsok, B., Száraz, J., & Gácsi, 2014, 166).

Recognition, Discrimination and Individualization

To stablish the unique relationship with the owner, the pet-robot should be able to discriminate him as the object of selective attachment and express towards him their behavior in an individual-specific way deploying this privileged relationship through distinguishable behaviors. On the other hand, appropriate individual variations of behaviors could contribute to perceive the robot as having a personality or being more vs. less dependent on the users.

Salient and Contingent Behavior

The robot should deploy an active and responsive mode of interaction that closely matches the modalities suggested by the life-like appearance of the device, that is to say, similar to real animals' action. Robotic pets should be able to interact timely and perform *in response* to people's actions rather than autonomously.

> […] it was still clear that they would have preferred Pleo to be more interactive and reactive during those sessions. This concerned not only its physical ability to move, but also its ability to react to sounds, follow objects, come when you call its name etc... (Fernaeus et al., 2010)

In this sense, connecting real but simplified cues, like for example an actual smell with sniffing behavior or lower temperature with freezing behavior could be a really engaging behavior reinforcing the robot situatedness (Jacobsson, 2009). But above all, what is more realistic is to connect ostensibly the pet's actions and states to the actions performed by the user (Fernaeus et al., 2010), providing timely responses to partner's actions, such as orientation, attention, monitoring, mood changes (emotional alignment) and long-term effects (training).

At present, most human-companion robots seem to behave as if they had been programmed with very little attention toward the human partner, being not capable to participate in the social interaction in a natural way because of technological constraints (i.e. sensoring, reaction speed) (Miklósi & Gácsi, 2012). When a child makes a social bid (i.e. speaks to the robot, offers a ball, approaches) the pet should respond contingently, promptly, and appropriately. According to the literature, robotic pet technology seem less effective than living dogs in supporting reciprocal and responsive interactions what could be an obstacle to integrate robotic pets into therapy since appropriate contingent responsiveness is itself a therapeutic tool.

Credibility and Consistency

Importantly, and in contrast to low-tech toys and dolls, the expectations about the pet-robots involves the performed skills of the robot, rather than relying only on one's own imagination (Fernaeus et al., 2010). In particular, critical abilities of the robot to convey credible performance are the ability to move quickly, to attend and to react to sounds, to orient to objects presented, to follow objects, to come when you call its name and to follow one's gaze (Fernaeus et al., 2010). Very often, the behavior of the companion robots is not in line with their embodiment. For instance, the movement capacities in terms of walking or running of the iCat, the Pleo and the AIBO that resemble family pets are also very limited moving much slower than the "real" animals they are inspired by. Provided movement in space and in relation to each other is crucial for meaningful social interactions, there should be a preference for rolling robots given the limits of present day technology (Á. Miklósi & Gácsi, 2012, 5).

Autonomy

Dautenhahn defines autonomy as the agent having its own goals that emerge as the function of inners states (i.e. motivations, emotions). Goal directed behavior of the agent provides perhaps the best information about autonomy in the eyes of the observer. The fact is that most of robotic pets show quite limited autonomy and they do not give the impression to be self-propelled (Miklósi & Gácsi, 2012).

4. Child-Pleo Dyad Behavior System

The aim of this chapter is to describe in detail and analyze the interactional system of children behavior with the Pleo robot, developed from an ethographic perspective, based on the model of bond forming proposed in Chapter 3.

Pleo is a robot in the shape of a baby-dinosaur programmed to enhance interaction with its owner in an intuitive open-ended base, playing with it and with the little items provided for such as pieces of *food*, toys and *candies* (Fig. 4-33). Spontaneous interaction most frequent observed with Pleo are feeding and petting (see Fig. 4-1).

Figure 4-1 Children interacting with Pleo

In addition to the self-initiated movements and sounds, and the responses to user actions, Pleo is programmed to go through three stages of development: newborn, toddler, teenager and adult. Different *needs* and behaviors are assigned to each stage. For instance, in the first stage, Pleo's activity intensity is low, is not capable to stand upright on their legs, and need to be nurtured and soothed to be *content*. The first two stages are usually completed within the first hour where Pleo slowly starts to move and interact and stays in the juvenile phase for the rest of its *life*. Pleo displays its behavior in interaction with the environment and with the user's activity, according to its internal motivational model. In use, the playing time is about one hour for a four-hour charge.

> Pleo is one in a row of recent robotic products entering the global consumer market. It is also profoundly different than most other robotic products in that it is designed from ground up to constitute a more believable motional and visual appearance as artifacts that hopefully would capture the essences of what people experience and interpret as life-like. (Jacobsson, 2009)

4.1. Introduction

In this chapter we describe first Pleo's morphology and basic skills as a subject in interaction, secondly the *space* within which the interaction between the child and Pleo takes place and thirdly Pleo's and child's repertoires of behaviors exhibited during interaction, considering two levels of granularity: behavior units and episodes. The focal subjects of the behavioral units are the individuals – child and Pleo respectively - while the subject of the episodes is the child-Pleo dyad. Finally, a coding-scheme derived from the behavioral system is applied to a set of video-recorded observations of children playing with Pleo, in order to be evaluated as a methodological tool to measure interaction and bonding.

4.1.1. Approach

Pleo as a Social Partner

The main feature of the behavioral system proposed is the fact that addresses equally and simultaneously both Pleo's and children's exhibited behavior as the two partners in a social exchange. Most surprisingly, in the reviewed studies on HRI with Pleo robot there is few or none description of Pleo's behavior during the encounters with children while the focus is kept almost exclusively on children behavior, as if Pleo's actual performance was irrelevant. This approach seems to consider the robot either an element of the context or a stimuli rather than a proactive partner in a dynamic dialogue or communicative episode (Filiâtre, Millot, & Montagner, 1986; Millot et al., 1988).

Nevertheless, there are noticeable exceptions to this *mainstream* in HRI research such as Pitsch's studies (Pitsch & Koch, 2010) that adopt the framework of conversational analyses where any communicative act is grounded on and takes its meaning from the flow of the social exchanges. We align with Pitsch's approach considering that Pleo's performed behavior really matters to understand child-Pleo interactive dynamics.

From our perspective, Pleo's performance in the course of interaction is relevant in children cognitions, performance and emotional involvement dynamics: "users seem not only (or primarily) consider the robot's physical appearance as grounds for their perceptions of a system but rather (or importantly) orient to systematic features of their interactional responsive conduct' (Pitsch & Koch, 2010). Therefore, our behavioral system, in line with Pitsch's position, aims to describe *how* Pleo deploys its particular social behavior as an agent, capable to engage children in meaningful sequences of action, without prior knowledge or explanation (Pitsch & Koch, 2010).

We dare to speculate that the lack of systematic descriptions and measurements of Pleo's behavior reflects some reluctance to consider Pleo's individuality –as *specimen*- and to address Pleo's variability performing in the real world. We consider that Pleo's unpredictability in the wild is the crux of the matrix of its life-likeness.

Purpose of the Behavioral System

The goal of the behavioral system developed in this chapter is contributing to the systematic investigation of children behavior both in a particular encounter with Pleo and over time. We consider the system as an on-going iterative process that can be used and modified by others researchers interested in investigating the ontogenesis of the child-robot relationship.

In particular, the behavior system aims at gaining understanding of i) whether and how children get (emotionally) engaged interacting with pet-robots, ii) whether and how a bond emerges from this interaction and finally, iii) how robot's behavior and situational variables affect this process of engagement and lasting relationship.

To illustrate the kind of data this system deals with let us imagine a typical sequence where a child in his second encounter with a Pleo runs towards the robotic pet, embraces it, kisses it on the top of the head and says 'I have missed you so bad!' while Pleo moves lively and purrs. This sequence accounts for both observable behaviors (e.g. hugs, kisses, baby-talk, purring) as well as for the inferred child's feelings underlying them (e.g. cheerful reunion, sorrow for the separation).

More precisely the child-Pleo behavior system aims to help to:

1. Identify and measure engagement as the prevalence of behaviors with, towards or related to the robot during interaction
2. Measure enjoyment and other subjective states during interaction that are relevant for bond forming through behavior indicators.
3. Identify patterns or sequences of *meaningful* and *relevant* –in terms of bond forming- interactive behaviors (e.g. feeding the dinosaur).
4. Identify the behaviors and situations that *elicit* child engagement and enjoyment.

4.1.2. Characteristics and Scope

According to the proposed model of bond forming (see Chapter 3), the behavior system includes i) the description of the context, ii) the child's behavior (e.g. the child presents to Pleo a leaf out of sensors' reach), iii) the robot's behavior (e.g. Pleo initiates walking ahead behavior), the dyad's behavior (e.g. three sequences of food offering-rejecting), and iv) the child perceptions and feelings (e.g. the girl banges on the table with the fist when Pleo's *refuse to eat*).

The system proposed is complex and multilayered, behavioral and data-driven, platform dependent and partial (focused on social behavior).

Complex and Multilayered

From our perspective and according to the model elaborated in Chapter 3 child-robot bond forming is a process that conforms to identifiable patterns of verbal and nonverbal behaviors with and perceptions and feelings towards the robot. Thus, the system encompasses both behavioral and socio-cognitive data. From our framework we assume that:

- Perceptions and feelings can be inferred –to some extend but sufficiently- from verbal and non-verbal behavior during the episodes of interaction with the robot.
- The patterns of interactive behaviors in an *encounter* influence and are influenced by the current bond between the child and the robot, and the actual flow of the interaction –in a mutual influence loop- jointly with other situational and individual variables (e.g. adults intervention, child's health condition).
- The episodes of successful interaction enhance the bond emergence and maintenance.

As can be noticed, the key variables of study are different in nature and some of them are observable and other must be inferred. As have been highlighted in previous studies, key social processes such us *attributions*, *trust* or *expectancies* are crucial to understand HRI but are not directly observable. As Lohse states (2010) referring to her focal concept of expectancies in HRI:

> ... the physical social situation, part of the contexts/goals, the behavior of the robot and the user can be observed and with their help the users' expectations and their perception of the situation can be inferred. In the following, methods are introduced that were developed and combined to research the observable factors of the interaction and to infer the non-observable factors. (Lohse, 2010, 55)

> … based on the contexts, people perceive the situations in a certain way and act according to how they understand what is happening. Therefore, how users perceive the interaction situation can be inferred from their actions and from the questionnaire data. (Lohse, 2010, 28)

Behavioral and Data-Driven

The system is behavioral in the sense that the descriptions focus on the *exhibited* behavior (i.e. the interactive practice) of both human and robots (i.e. bottom-up approach) rather than on the underlying processes.

Similarly to behavioral biologists who focus on exhibited behavior of living creatures rather than on the biological processes, we share with the *behavioral roboticists* (Arkin et al., 2002, 2001) the primary focus on robots' performance rather than on computing (architecture and software) what is the usual focus in the field of artificial Intelligence (Baxter, 2007). Similarly to Arkin's ethological model (Arkin et al., 2002) our work seeks to extract from observational behavior (not neuroscientific models) suitable descriptions of activity that can be effectively mapped onto robotic systems to provide the appearance of life-like activity.

The system proposed is data-driven, drawing from the observational data gathered in different studies in the lab and *in the wild* in different scenarios and contexts (see Table 4-1 and 4-2). All the behaviors reported and described have been directly observed.

Platform Dependent

This system is not presumed to organize and describe all possible child-pet-robot interactive behaviors in general but just a set of interactive behaviors contextualized to a particular *space* (see Section 4.3.1.) delimited mainly by the robot features and the context of the interaction.

One of the greatest challenges HRI research faces is that the interactive behavior with robots is extremely platform dependent. The repertoires of interactive behaviors are restricted by the particular robot's morphology (e.g. mobile lips, eyelids, tail), low level skills (e.g. tactile sensing, limbs degrees of freedom, mobility) and competences (e.g. sound-orientation, face-detection, eye-tracking, vocalization) that vary dramatically from one *species* to another even between platforms belonging to the same class of pet-robots.

> The main problem with universal coding schemes is that the behaviors are determined by the situations. Thus, universal coding schemes would have to be very general and abstract to be applicable for many situations and much information would be lost in the analysis process. Therefore, coding schemes need to be data-driven to actually include the behaviors that occur in

> a certain situation. Moreover, the coding schemes depend on the research goals that strongly influence their content and the granularity with which behaviors are coded. (Lohse, 2010, 56)

In spite of this hindrance, we expect that the highest level functional categories (e.g. giving affection) could be suitable to study children interacting with other pet-robots, as a general *template* to customize behavioral systems for investigating other platforms, in other contexts and addressing other research questions. On the other hand, the more fine-grained molecular units (e.g. scratch the chin, quiver the tail) are unavoidably less general because they are delimited by each platform's morphology and basic skills.

4.1.3. Structure

The behavioral system of child-Pleo interaction encompasses i) the robot's morphological or structural description (Section 4.2.), ii) the ethogram of Pleo's behavior (Section 4.4.), iii) a catalogue of children's behavior interacting with Pleo (Section 4.5.), and a catalogue of dyadic (child-Pleo) episodes of contingent social behavior (Section 4.6.).

Robot's Morphological or Structural Description

A robot is an object, a physical artifact and its morphology is the result not of *evolution* but of many decisions on shape, materials, elements, color, texture, size, mechanisms. Even though robots are classified according to their morphology into different categories (e.g. mechanoid, zoomorphic, humanoid and androids at the extreme end of human-likeness Hegel et al., n.d.; Kerstin Dautenhahn, 2016) each platform features specific structural traits that enable specific competences. Similarly to biological creatures, morphology is the potential and the limitation of robot's behavior.

Furthermore, in social robots their morphology become their *appearance* that influences key aspects for successful interaction and bond forming such as attitudes, expectancies and judgments (Pitsch & Koch, 2010). These structural characteristics can be considered as social *affordances* (Díaz et al., 2011; Gibson, 1986) as long as they support children's perceptions on and guesses at robot's functionalities.

Thus, we consider that a morphologic-structural description of the robot in terms of appearance, structure and technological resources for social performance has to be undertaken to delimit the social space for current interaction (see Section 4.2. *Robotic Pet Pleo*).

Pleo's Ethogram

An ethogram is a complete and systematic behavioral repertoire of one species in its natural environment (Riba, 1988). We consider that the repertoire of Pleo's behavior presented meets sufficiently these requirements to be considered an ethogram.

Although from Pleo's *perspective* as a toy every action is social (i.e. addressed to the player or to a potential player), the focus of Pleo's ethogram is placed on behaviors that convey clear social meaning, this is to say, that can be read by the human partner as social cues during interaction (e.g. inviting to act, providing feedback).

The inventory presented tends to be a complete repertoire of exhibited behaviors and includes not only molecular behaviors (i.e. micro-behaviors K. Dautenhahn & Werry, 2002) (e.g. rise the head, open the mouth) but also more molar behaviors (e.g. threaten display) with descriptions of movements, position and orientation of body and body segments as well as vocalizations.

Inventory of Children's Interactive Behaviors in Free-Play with Pleo

The repertoire of children behavior with Pleo is partial –only focused on the interactive behavior- and more importantly, restricted to the contexts observed, without the pretension of completeness a real ethogram has. Therefore, we consider this system a catalogue or repertoire understood as "a sample (not exhaustive) of all the possible behavioral units of the species that is obtained from observation during a limited time span" (Riba, 1988).

Inventory of Sequences of Significant Contingency

This inventory encompasses patterns of dyad's reciprocal interaction mainly epimeletic (i.e. care and attention giving), etepimeletic (i.e. attention getting and care soliciting) and play behavior. To be considered a dyadic pattern in our system, a sequence of behaviors should include one bid (e.g. offering Pleo a leaf) and a contingent situated response (e.g. opening the mouth) and can be initiated either by the child or by the robot.

4.1.4. Methodology and Antecedents

Pleo's and children's behavior catalogues are built using the corpus of video-taped data from preliminary studies, covering the different phases of the process of elaboration of a behavioral inventory -free observation, description, interpretation and contextual analyses (Riba, 1988). Tables 4-1 to 4-3 summarize key information of the studies: the setting, the number and profile of participants and, when available, other complementary data obtained. The observational database covers children interacting with Pleos in different contexts and situations to ensure capturing a wide range of behaviors and individual variations of similar behaviors in descriptively different ways. Some of these observational data had been partially analyzed in previous publications that are referred as well in the tables.

Three exploratory studies were carried out in the lab and at school before addressing our target group of hospitalized children. The objective of this series of studies was twofold: i) gaining understanding of the potential of different kind of social robots and specifically pet-robots to engage children and at describing the interactional practices children spontaneously deploy with the robots and ii) develop a methodology for investigating children's interactive practice with and perceptions towards the robots. (Díaz et al., 2011; Diaz, Nuno, Saez-Pons, Pardo, & Angulo, 2011; Díaz M, Saez-Pons J, Nuño N, 2010).

After the exploratory studies and from lessons learned observing children playing with different types of social robots, we focused on child-Pleo interaction investigation.

Table 4-1 Summary of author's previous studies on children-pet-robot interaction

Study/Publ.	Participants	Place	Setting	Observational Data	Questionnaires	Interviews	Other
In the lab Preliminary 2010	N = 1 Normative child 11 years Girl	Interactive Behavior and UX Lab	– With a conductor face-to face – Talking about Pleo and exploring	– Video recorded by the lab cams			
Sant Jordi Primary School (Diaz et al 2011) 2010	N = 49 Interacting with Pleo = 18 Normative children 11 to 12 years Girls	At the school – First in the main hall (choice) – Then in a classroom (workshop) – Wrap up in the main hall	– All together selecting the robot – Workshop on robotics in a class room	– Professional photographic reportage – Video recording opening in the hall (all together) – Video recording of the workshops in the class room – Video recording closing in the hall (all together)	After the workshop, covering: – Reasons for preference – Expectancies – Improvements/Wishes – Judgments	Small group interview with the workshop participants, on the fly, at the class room, small group, before starting the workshop	
In the lab from Sant Jordi Study (Diaz et al 2011) 2010	N = 4 Normative children 11 to 12 years Girls	Interactive Behavior and UX Lab	– Introduction with conductor – Individual Play – Play with a mate	– Video recorded by the lab cams – Video recording focus group			Focus group with the 4 participants
Margalló Primary School 2011	>100 Normative children and children with special needs 3 to 12 years	At the school – First in the main hall – Afterwards in separated classroom (workshops)	– Children all together selecting the robot – Workshop in a class room	Video recording only workshops	After the workshop		
Montserrat Primary School (Heerink et al 2012) 2011	N=28 Normative children 19 Boys /9 Girls 7 to 11 years	At the school	– At the school TV studio – Free play in pairs – Three cameras	Video recordings from 3 cameras	After the workshop covering: – Experience – Social presence		

Table 4-2 Summary of studies on Children-Pleo interaction analyzed in this dissertation

Study/Publ.	Participants	Place	Setting	Observational Data	Questionnaires	Interviews	Other
Guipuzcoa Primary School 2011	N=12 Normative children 6 Boys /6 Girls 10 to 11 years	At the school	Empty class room 2 cameras Free play in pairs	Video recordings from 2 cameras	After the workshop covering: – Experience – Social presence		
Sant Joan de Déu Etnography I 2014	>270 Children in the Hospital facilities hospitalized or in external consultancies (See tables 5-3 and 5-4 for details)	– Outpatient visits units – Hospitalization wards, – Pre-surgery waiting rooms – Play room at Oncology Ward – Main play room – Teenagers play-room special session "Pleos' place" – Outpatient Oncology Center		Field diaries from team members		– Volunteers – Parents in the longitudinal study	Follow-up team meetings (video or audio recorded)
HSJD Workshop « Pleo goes emotional » 2014	N=14 In patient children accompany by relatives (children and adults) 9Boys /5 Girls 2 to 8 years	At the Hospital at the main play-room	3 cameras Pleos place in a corner Designed as a Workshop, finally Free play Pleos' corner	Video recordings from 3 cameras			
Sant Joan de Déu Etnography II 2015	Children in the Hospital facilities hospitalized or in external consultancies	At the Hospital – Outpatient visits units – Pre-surgery waiting rooms – Play room at Oncology Ward (Oasis room in 8th floor) – Children rooms at Oncology Ward – Outpatient Oncology Center		Field diaries from the in the field team members			

Table 4-3 Summary of children interacting with social robots observations in previous studies Participants' genre and age, studies' design, setting, social scenario and type of data

Study	**Participants**					**Ses.**	**Data**		
		Genre		Age					
	N	Boys	Girls	Min	Max		Video	Quest	Other
In the lab (preliminary)	1	0	1	11	11	1	YES		
Montserrat Primary School	28	19	9	6	12	14	YES	28	Pleo's Logs
Guipuzcoa Primary School	12	6	6	11	12	6	YES	12	
Sant Jordi Primary School	49	29	20	11	12	4	YES		
Pleos workshop	18	0	18	11	12	1	YES	18	
NAO workshop	14	12	2	11	12	1	YES	14	
AIBO workshop	7	7	0	11	12	1	YES	7	
SPYKEE workshop	10	3	7	11	12	1	YES	10	
In the lab from Sant Jordi	4	0	4	11	12	4	YES		Focus Group
Margalló Primary School	23	9	13	9	10	2	YES		
Pleos workshop	8	1	7	9	10	1	YES	8	
NAO workshop	15	9	6	9	10	1	YES		
4 robots All children	>100			3	13	1	NO		Drawings
HSJD Ethnography I	271			<1	18		NO		Field Diaries Interviews
Pleo goes emotional	14	5	9	2	8	1	YES		
Longitudinal	1		1	4			NO		Interview
HSJD Ethnography II	>150			<1	16		NO		Field Diaries Interviews
Waiting room Emergencies	>40			1	15	4	NO		
Waiting room Allergies	30						NO	30	
Total	822								

In total 203 children were video recorded interacting with social robots. From these, 85 children were interacting with Pleo, 54 girls and 31 boys aged from 2 to 13 years old. The episodes with Pleo were gathered in different settings: 5 girls playing alone, 40 children playing in pairs and 40 in group. 5 children were observed in our lab, 66 at school and 14 at the hospital.

With respect to the robotic partner, many different *specimens* of Pleo have been observed –up to 20- varying from mild morphological differences such us the color and patterns of the blotches in their mottled back and the color of their eyes, development stages, maintenance state -from brand new *specimens* to some with noticeable signs of deterioration by use (e.g. continued rubbing wear away the colors of Pleo's skin).

Provided that in these studies the emphasis was primarily on children behavior, the robot's internal *individual variables* were not gathered. Pleo's internal variables configure its permanent traits as *personality* or *gender*, and temporal states as development stage, *mood, emotional state, hunger* or *playful disposition*. These internal variables along with the situational variables determine Pleo's particular behavior.

Nevertheless, in one of the studies at school we registered the value of the internal states, -that could be accessed through communication from a laptop with an application developed *ad hoc*,(see Fig. 4-2). The values were registered at the beginning and at the end of each interaction session. Finally, we did not use this logging data in the analyses. However, in line with Pitsch we consider that to link the behavioral data with logging data showing the system's internal states is a relevant methodological issue to be taken into account in further research (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012; Pitsch & Koch, 2010).

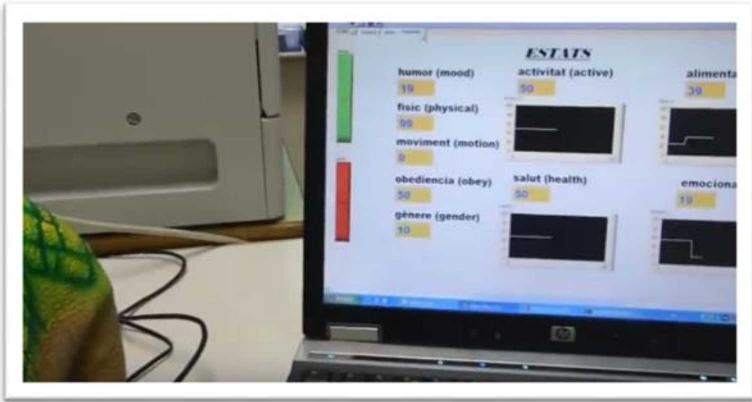

Figure 4-2 On-line display of Pleo's internal estates variables

Differently from children's behaviors, Pleo's molecular behaviors (e.g. bite) are quite stereotyped and presents only small variability intra and between individuals in the same occurrence context, apart from malfunction or deterioration that it is not unusual after several hours of intensive exposure to children play. This low variability in the individual expression of a behavioral unit is one of the stronger arguments to support the concept of ethogram as an attainable repertoire of fixed patterns of behavior (Riba, 1988). In addition, this invariability allows reducing the requirement of sampling observation time to complete the ethogram.

4.2. Robotic Pet Pleo

In this section, a description of Pleo's morphology (embodiment) and basic skills is provided, with an emphasis on the communicative value of its appearance and performance.

To put Pleo's features in context, a comparison of the main characteristic of 5 popular pet robots –popular in research and in the market- are summarized in Table 4-4. The pet-robots? features are organized according to its *naturalness* –degree of bio inspiration- into *Natural* and *Not natural* cues. A description of the general appearance and a check list of the most common elements supporting pet-robot's capabilities to communicate with children (affordances) are provided.

The echnical specifications and descriptions are draw from the company web site[21] and from the works of Raya (Raya Giner, 2014), Larriba (F. Larriba, C. Raya, C. Angulo, J. Albo-Canals, M. Díaz, 2015) and Joensten (Mathieu, 2014).

4.2.1. Embodiment

4.2.1.1. Appearance and Features

Ugobe's Pleo robot is a 20-cm high, 50-cm long –roughly the size of a cat- entertainment robot in the shape of a baby dinosaur, covered by a rubber skin over a mechanical frame. From the co-creator of the *Furby* -the famous owl shape robot pet toy- this emulated pet wide cranium and body shape allows the incorporation a series of sensors and actuators needed to provide it with life-like activity and development.

[21] http://www.pleoworld.com

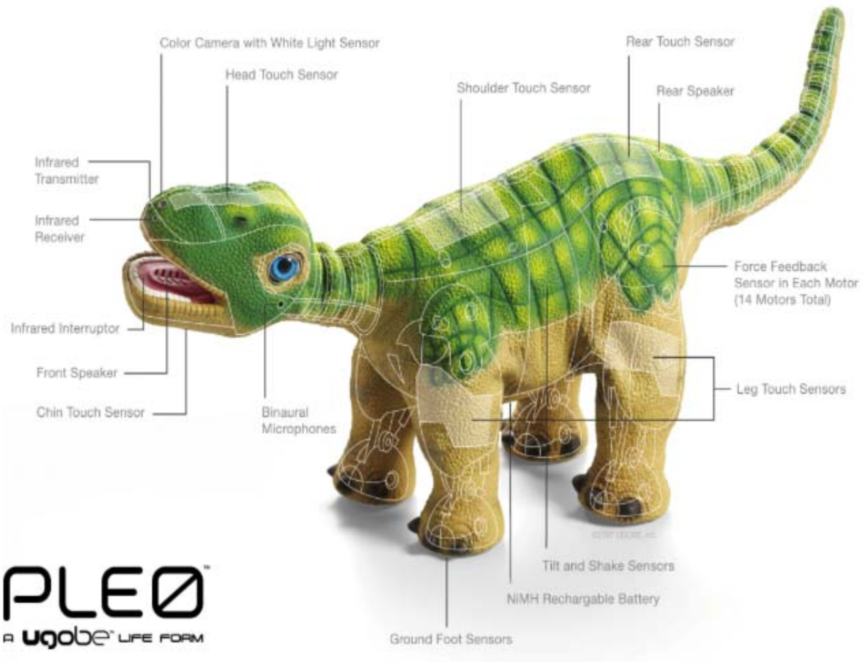

Figure 4-3 Pleo embodiment
Source: Amazon https://www.amazon.com/Pleo-Dinosaur-UGOBE-Life-Form/dp/B000RWEGCO

As a product, Pleo comes wrapped up in a green cardboard box long with a battery, a recharger, a small brochure, a green plastic leaf, as well as a unique ID card. The ID card is used to register the product and also allows the owner to start an online blog account.

4.2.1.2. Technological Resources for Bio-Inspired Performance

Compared to most other toys, Pleo is technically very sophisticated. Pleo features two speakers –a smaller one in the jaw and a larger one just above its tail- and a camera mounted on the nose- with a sensor that allows the detection of bright light, darkness and color, as well as motion, and the registration of object located directly in front of it. It can also do snapshots that are processed to identify objects and to track them (Fig. 4-3).

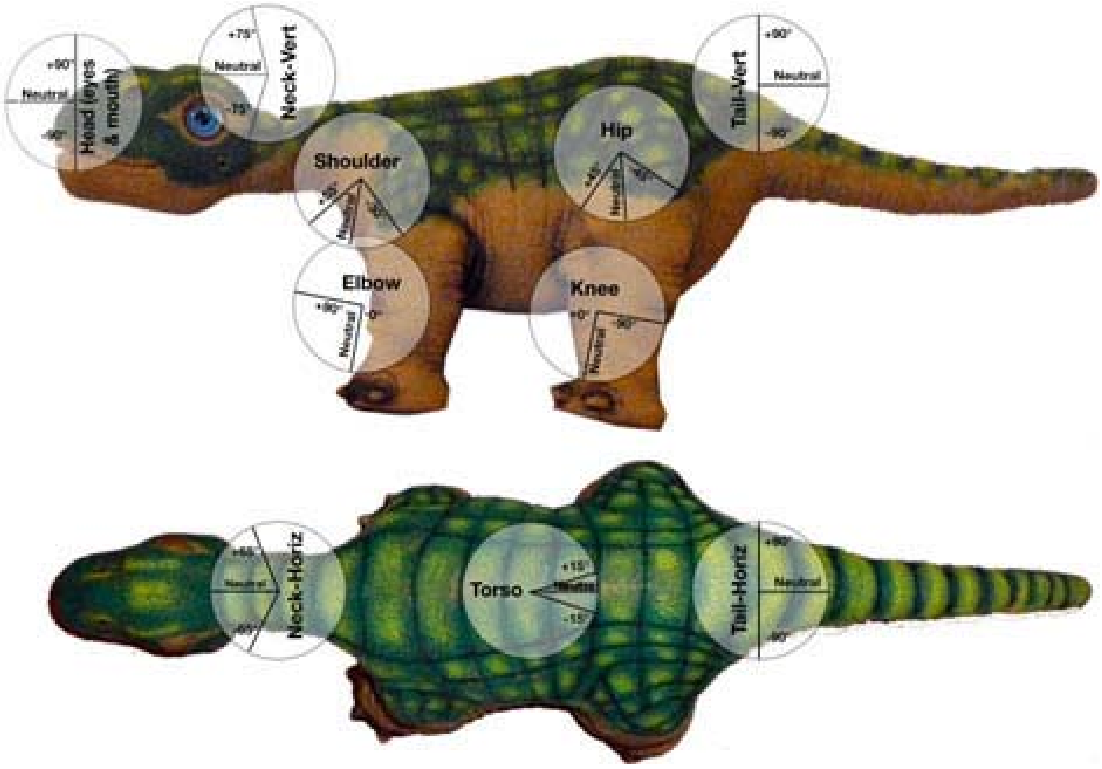

Figure 4-4 Diagram of Pleo's joints and range of motion
http://www.geekalerts.com/pleo-news-for-developers/

Pleo is provided with fourteen motors that allow its bio-inspired motion: two articulations in each leg, one motor for every elbow and shoulder and another for the hip and the knees, two more two move the head and two more for the tail -to perform vertical and horizontal movements-, one motor is used to move the torso, and finally, the last motor allows opening the mouth and closing the eyes. In fact, the Pleo cannot close the eyes when its mouth is opened and inversely (see Fig. 4-4).

The robot is composed by twenty sensors: eight are touch sensors under its rubber skin, situated on its back, on its head and on its legs. They are capacitive sensors that are active when they are in contact or close proximity to the skin of a human. A switch is installed under each paw of the dinosaur to detect whether it has contact with solid ground or no. Pleo has got an infrared transceiver used to communicate with its mates. In addition it features two infrared sensors –one on the nose and one in the mouth- and two microphones positioned slightly below the eyes able to detect the sound direction.

Pleo is featured as well with a Radio Frequency Identification (RFID) sensor under the head to detect different items presented at the required distance and position (e.g. offering food), and with an accelerometer which reads the orientation, inclination (tilt function) and if the pet is shacked (a game force feedback sensors).

The controllers used inside the Pleo are two ARM7 32-bit processors. The first one is situated inside the head and is used to manage the camera, the sound inputs, the IR communication, the RFID sensor and the touch sensors on the head. The second controller is situated inside the body of the Pleo and handles the motor control, the rest of the touch sensors, the speaker and the high level of the native Pleo software and four small 8-bit micro-controllers for the paws motor control. External interfaces include an SD-card slot, Micro-USB and a hidden debug-port.

4.2.2. Performance

Pleo's performance is aimed at creating a believable creature-like behavior with life-resembling properties such as cyclic and developmental patterns of behavior according to internal states, environment, *maturation* and learning.

Pleo is interesting as a robot because -like many other toys- it does not prescribe a set of specific activities or games for the user, but instead encourages open-ended exploration and play (Fernaeus, Håkansson, Jacobsson, & Ljungblad, 2010).

Its behavior evokes this of pet-animals as a combination of dogs (e.g. bite behavior) and cats (e.g. tail movements, purring) displays. In a typical interaction episode with Pleo, when a user strokes its back, the robot will indicate that this interaction is perceived as pleasant (e.g. purring noises, craning the neck towards the user). On the contrary, if Pleo is put into a dark box or handled roughly, it will make plaintive or angry sounds. If it is hit strongly, the force feedback sensors will initiate a shutdown and Pleo will move less, as if the robot needed time to recover from the abuse. Pleo detects whether something has been placed in its mouth which is meant to simulate food and then Pleo may bite the object and utter sounds as if chewing (Fernaeus et al., 2010; Rosenthal-von der Pütten et al., 2014).

This category of toys is a considerable challenge for designers, not only because they are built for open-ended interaction but also because its relatively high price rise expectations on a lasting long-term mode of interaction (Fernaeus, Håkansson, Jacobsson, & Ljungblad, 2010).

According to the model of bonding presented in Chapter 3, Pleos appearance and competences seem to map the key performances of successful interaction and bonding. Pleo's skills and behaviors supports credible nurturing exchanges as feeding and smoothing, express internal states as anger, hunger and fear; react both to external events and to internal states, and last but not least, evolves growing up and learning new behaviors that stimulate and reinforce the interaction beyond the novelty effect.

Users and developers have three ways to interact with Pleo robot: i) through social spontaneous open-ended play, ii) activating Pleo with specific manipulations or commands, and iii) through software programming. Pleo's spontaneous activity encompasses the behaviors that Pleo performs when it is alone or in the course of interaction, without being triggered by a deliberated activation by a human. These behaviors are autonomous (i.e. not controlled), basic (i.e. not learned) and *natural* (i.e. they appear during interaction without application of a pre-determined protocol). Instances of spontaneous behaviors are walking ahead, roaring, open the mouth, blinking, bowing, and raising a leg (see Section *4-4 Pleo's Ethogram* for the ethographic description of Pleo's behaviors). Spontaneous behaviors displays both Pleo's self-initiated activity (i.e. driven by internal states) and the responses to users' behaviors in the flow of interaction. This *dance* of mutual influence between internal motivations, contextual occurrences and users' actions are the base of child-Pleo self-organized play and the key feature of Pleo life-likeness.

The second way to interact with Pleo is activating it directly by *ritualized* manipulation or specific verbal commands after a standardized *training*. This behaviors has to be triggered by deliberate, non-intuitive (i.e. it is not possible to be discovered by players without help) and no bio-inspired actions that have to be learned (e.g. from manuals, websites or users' blogs).

It would be interesting to compare the influence of spontaneous vs activated behavior on the construction of children perceptions on Pleo's nature. As a working hypothesis we think that the more realistic according to life-likeness and pet-likeness essences, the stronger the *agentive illusion* (Meltzoff et al., 2010), the attribution of social awareness and the potential of engagement. In this sense, while *tricks* and *learned* behaviors are funny and amazing –some of them are quite sophisticated and complex performances- they lack consistency and naturalness according to a realistic (i.e. credible) animal-likeness. These performances are closer to what we would expect from anthropomorphized and/or cartoon characters than to real animals (i.e. burst of laughing, singing a song) what can enhance its role as distractor while weakening its role as credible pet.

Finally, Pleo's behavior can be controlled by software programming what is not a primary use of the robot and is not contemplated by the sellers as an *add on* to the physical interaction. Though featured with SD readers and USB and other communication interfaces, Pleo is not a platform supporting users' programming as an expansion of the robot capabilities, as other social robots as AIBO or NAO. In fact, only experienced programmers investigating specialized websites or user's blogs can manage to reprogram Pleo's routines.

Table 4-4 Robotic-pets' embodiments. Pleo, PARO, AIBO, ROMIBO, and Karotz

    

Natural cues	Appearance/Basic Form	**Age**	Babylike	Babylike	Baby/Adult-like	Babylike	Babylike
		Bio/Techno	Biological	Biological	Mechanoid	Toy/ Mechanoid	Toy/Animal
		Realistic	Identifiable	Identifiable	Identifiable	Fancy	Identifiable
		Surface	Rubber	Fur	Plastic	Fur/Plastic	Plastic
		Texture	Stiff	Soft?	Stiff	Stiff	Stiff
	Head/Face	Head	✓M (Mobile)	✓M	✓M	✓M	✓
		Mouth	✓M	✓M	✓M	✗	✓
		Eyes	✓	✓M	✗	✗	✓
		Eyelids	✓M	✓M	✗	✗	✗
		Eyelashes	✗	✓?	✗	✗	✗
		Eyebrows	✓?	✓	✗	✗	✗
		Nose	✓	✓	✓	✗	✓
		Ears	✓	✓	✓M	✗	✓M
		Whiskies	✗	✓	✗	✗	✗
	Body	Arms	✗	✗	✗	✓?	✗
		Hands	✗	✗	✗	✗	✗
		Fingers	✗	✗	✗	✗	✗
		Torso	✗	✗	✗	✓M	✓
		Legs	✓M	✗	✓M	✗	✗
		Paws	✓	✗	✓M	✗	✗
		Feet	✓M	✗	✓M	✗	✗
		Flippers	✗	✓?	✗	✗	✗
		Tail	✓M	✓M	✓M	✗	✗
		Ants	✗	✗	✗	✓M	✗
Non-natural					Lightings Projected shapes on a screen in the face	Lightings Projected shapes on a screen in the face	Lightings Projected shapes on a screen in the face and torso

Note: a *M* after a tick indicates that the element is mobile

4.3. Child-Pleo Interaction

This section addresses the data driven system of the exhibited behaviors of child-Pleo dyad in the course of interaction. First, we delimit the *space* within which child-Pleo interaction takes place (4.3.1.) and the methodological issues (4.3.2.). Secondly, the ethograms of Pleo's behaviors and of children's behaviors are presented separately (4.4. and 4.5.) and finally a selection of significant sequences of reciprocity between children and robot is discussed (4.6.). The three repertoires of behaviors –Pleo's, children's and dyad's- are driven from observational data gathered in studies that covers different physical and social contexts (see Tables 4-2 and 4-3).

4.3.1. The *Space* for Child-Pleo Interaction

The space within the interaction unfolds is the subjective, dynamic and socially constructed frame of possibilities – physical, social and even moral- for *using* and *relating* to Pleo. Is in this space where behavior is thought, perceived, anticipated, interpreted, planned and performed. This social and symbolic space makes sense to at least the following issues *What is likely to happen next? What could one do with Pleo? What should one do with Pleo?*

This space is defined and delimited first by the possibilities and constrains provided by Pleo morphology and performative resources (Section 4.2. and Table 4-4) but also by the way the child reinterprets them as social affordances in the particular context (i.e. physical and social situation) in interaction with individual variables.

Unconstrained Free Play Context

The typical interaction with Pleo is unconstrained open-ended play supervised by an adult, without predetermined external instructions or blueprint. Pleo's small size and harmless appearance together with its triple *nature* of toy, pet and baby enable full-body interactions. The situation seems to be assimilated by children as a self-organizing *free play* and elicit a one-up situation as owner. The free play frame together with the owner-pet position result in children's perception of being allowed -even expected- to freely explore the robot and to take the initiative. Pleo's baby-like appearance and its inability to satisfy its own needs autonomously (e.g. differently from other pet-robots Pleo is not capable to *forage*) reinforce the asymmetry and complementarity between Pleo's and child's respective roles. Pleo is easily regarded by children as a needy helpless charming baby-pet. According to this perception, a space for resources claiming-providing and play behavior is intuitively framed. In addition, adults' intervention interpreting, modeling, encouraging or limiting child's activity influences dynamically the interaction within this space, and consequently, the exhibited behavior.

The small size of Pleo offers a wide range of possibilities for examining, handling, tinkering and carrying the robot. Stationary platforms like I-cat (Fig. 4-5 a) and Karotz (Table 4-4) or bulky robots like Paro (Fig. 4-5 b) configure a more restricted space for manipulations where behaviors such as picking the robot up, holding it or carrying it are not possible or extremely difficult.

a) b)

Figure 4-5 Robotic Pets
a) I-Cat[22] b) Paro[23]

In addition, Pleo's nature as a sophisticated *smart* device incites the active exploration and investigation to discover its capabilities and pushing its limits, in the belief that the interest of the game depends importantly on the wisdom of the player like in video-games.

Unconstrained Social Scenarios

As an open-ended game, playing with Pleo allows different kind of social configurations, being the simplest the triadic situation with one child playing with one Pleo supervised by one or more adults. Nevertheless, playing with Pleo allows any sort of complex social configurations that can vary dynamically introducing new partners that eventually take active part in the interaction with Pleo. The encounters with Pleo are often a collective experience with more or less emphasis on the dyad child-Pleo and with variable participation and initiative of other agents that can join the game at any time. The collaborative nature of playing with Pleo allows

[22] https://www.youtube.com/watch?v=SgxdxP0UxwQ
[23] http://novista.se/english/products/paro

graduating and adjusting the symbolic situation and the interactive practice with the contributions of other participants.

In therapy related interventions the more frequent setting is an individual encounter between one child and one robot, situation that reinforces the owner-pet dimension in the symbolic play. However, a collective play is a promising alternative specially when the child feels not capable to –or not willing to- provide the cares that the perceived owner-pet situation requires (Kidd, Taggart, & Turkle, 2006). Actually, in pediatric contexts the introduction of Pleo can be easily and naturally adjusted to the more suitable social configuration according to each child's needs, ranging from the uniqueness of individual –supervised- ownership to a shared, collective game.

4.3.2. Methodological implications

The plasticity of Pleo's makes the systematic study of child-Pleo behavior during play very challenging. Pleo's unpredictable behavior along with the children's unpredictable behavior in unrestricted open-ended free play is a highly dynamic scenario, submitted to frequent external influences and events that result in high variability of situations and consequently, a wide range of different subjective experiences.

Therefore, systematic observation of child-Pleo interaction is more difficult than in other HRI cases when some sources of variability are more easily controlled. This control can be implemented by means of i) fixing the relative position and orientation of the dyad in stationary robots such as I-cat (Fig. 4-4 a) (e.g. sitting face-to-face in close distance), ii) defining the activity or task to be performed (e.g. playing chess), iii) defining the rules of interaction (e.g. turn taking, screen mediated interaction), iv) introducing protocoled modalities of interaction (e.g. speaking out in front of the robot's face, touching the head to turn it on, using conventional verbal commands).

4.4. Pleo's Ethogram

According to (Martin & Bateson, 2007)

> …an "ethogram" is ostensibly a catalogue of descriptions of the discrete, species-typical behavior patterns that form the basic behavioral repertoire of the species. Unfortunately, published ethograms vary enormously in the number of behavioral categories included and the detail with which these are described, and ethograms are unavailable for many commonly studied laboratory subjects (p. 34)

According to Riba (1988) the ethogram is not only an inventory but also a model of the adaptive competence of a particular species:

> The contribution of ethograms as inventories of behavior is twofold. On one hand gives support to the register techniques or behavior sampling based on this inventory, and one can consider the ethogram in this sense as an observational tool that guides the information gathering. On the other hand, an ethogram is a model of the adaptive competence of each species to which its built for, competence expressed, of course, through the species specific behaviors (p.139)

In the case of building a behavioral system of a non-biological *species* the second meaning of ethogram –a description of the adaptive behavior of a particular species as a result of its interaction with the environment- seems not to be applicable.

Provided that the existence and features of a particular species of robot is not submitted to the rules of evolution but to the designers' and engineers' decisions, the actual robot's behavior does not express the result of evolution but an intended functionality or purpose –as any other artificial entity. In this sense, Fagen's smart formulation of ethogram as "representing the conditions under which the intelligence operates in its interaction with the environment" would not be applicable to robots' performance (Fagen, R. M., & Young, 1978).

Furthermore, provided a robot is a designed creature, it could seem paradoxical to proceed inductively and build a bottom-up repertory of robot's behaviors from observation. A robot is by definition an artifact that *just* runs pre-programmed routines that produce its performance. In this sense, in the case of robots, one knows its performance *in advance*, that is to say, before been actuated. Differently from biological creatures a robot is a *white box* programmed to behave according to predetermined and defined rules.

However, we have adopted a behavioral approach in the study of Pleo's interactive behavior focusing on the *exhibited* behaviors in the *interactional surface* (Pitsch & Koch, 2010) rather than on the programmed competences. The meaningfulness of Pleo's behavior –if any- does not rely on the intended performance according to the software rational but on what is actually acted in the real situation. In an interactive sequence with a child, it is irrelevant whether Pleo indeed reacted contingently upon a particular child's bid or whether Pleo's action simply occurred by chance.

The reasons why we adopt this behavioral approach are:

- In the real world, robots do not always perform as expected by developers and programmers.
- Our focus is the participant's interpretations of the conduct in the context in which it occurs.
- In the real world, events do occur beyond the scope of foreseen circumstances taken into account by developers/programmers. As in any social system, in the course of interaction with Pleo accidental events –not so rare in this context- play an important role (Steenbeek & Van Geert, 2005, 7) such as Pleo *falling asleep* (i.e. run out of batteries) or sudden limbs or neck blockage.
- Social robots designed to be interacted with children in mostly free-play and unknown environments are exposed to a wide range of situational variables.
- Pleos are open-ended learning robots which behavior evolves according to multi determined factors over-time –including learning, deterioration and malfunction- making a particular behavior in a particular situation practically unpredictable
- Pleos are highly interactive agents that respond to specific stimulus (e.g. noise, darkness) or to partners' acts with different behaviors.
- From our functional approach, only observable behaviors are considered to have any effect in the actual interactive sequence. For instance, subtle changes that are not noticeable by users (i.e. a low vocalization in a noisy environment) has not communicational value and are not considered (i.e. are not *pertinent* according to linguistic models) even though they are behaviors from the point of view of the program run.

4.4.1. Categorization Criteria

The catalog has been separated into two main sections according to the degree of autonomy of the robot behaviors: *Spontaneous Activity* and *Activated Performance* (see Section *4-2 Performance*).

Spontaneous Activity encompasses the behaviors that Pleo performs when it is alone or in the course of interaction without being triggered by a deliberated activation by a human. These behaviors can be of different granularity ranging from very simple behaviors (e.g. open the mouth, blink) to more complex patterns (e.g. contorting when being hold by the tail, walking ahead).

On the other hand, *Activated Performance* includes behaviors that are triggered by *ritualized* manipulation or specific verbal commands after a standardized *training*. According to the activating process there are two kinds of activated behaviors: *Tricks* that are behaviors triggered by a particular manipulation, and *Learned behaviors* activated by verbal commands after a complex –and often eventful- learning protocol. Some of these behaviors lack the *naturalness* of Pleo's spontaneous activity and results bizarre in an animal-like creature (e.g. burst of laughing or sing).

It is worth noting that spontaneous does not mean either context-independent or innate. Actually, some of these behaviors only appear after a process of Pleo's *maturation* or *learning from experience*, and some of them are stage-specific behaviors that appear over Pleo's *life*-span adding new capabilities for interaction.

Spontaneous and activated behaviors are not two independent repertoires. While some behavior units are exhibited only through activation (e.g. burst of laughing) other behaviors can be both initiated spontaneously or through deliberate activation. For instance *Walking ahead* can be observed both as a self-initiated behavior or activated when the child utters the verbal command "*Come!*" after a process of training with the *learning stones.*

In a strict sense only the autonomous behaviors of Pleo could be included in the ethogram, according to conventional ethographic criteria (Martin & Bateson, 2007). However, provided the purpose of the present inventory is to identify *engaging behaviors* playing with Pleo we consider that is interesting to register and include in the repertoire all the behaviors observed whatever its *nature*. From this perspective, all exhibited behaviors are relevant to study child-robot interaction and all of them could eventually be used to design Pleo's performance or used in a Pleo-based intervention. However, what can be discussed is whether the use of the term ethogram is appropriate or it is better to use the term behavior repertoire or catalogue.

A third category *Inactivity* encompasses Pleo's shut down when the batteries are drained out (*Collapse*d) and Pleo in off state (*Off*). In these two states Pleo's postures are different and so is the way to turn Pleo on –awake- and these differences can influence the flow and narrative of the game.

At a second level, *Spontaneous Behavior* is separated into two sub-sections *Nonsocial* and *Social* behaviors, according to the degree of *socialness* involved. *Social* category is not restricted to affiliative behaviors, but includes as well Pleo's aggressive displays, that often elicit enjoyment in children and adults and even tenderness.

We consider *nonsocial* a behavior when there is not an intention to communicate neither to interact in any way, from *Pleo's subjective perspective*. We are aware that is controversial to sustain that a toy robot designed to provide entertainment through interaction can display any behavior that does not pursue an effect on users. Even in performing system oriented actions the toy's performance might be considered social while provokes amusement, entertainment, wonder or amazement. In this sense any Pleo behavior should be considered always social in the sense that is addressed to children and aims, at least, to attire attention. However, our decision in this case is to adopt a subjective perspective and to consider social only the reactive or pro-active behaviors that aim at eliciting a reaction on user.

In our system only *Locomotion* is an instance of non-social behavior because seems to respond to an internal drive (i.e. exploration), in absence of any previous specific interactive behavior of the user. Moreover, locomotion only appears when the space is cleared off and there is no physical contact, fact that reinforces its internal driven nature. Though locomotion is very seldom observed mobility is not Pleo's strong point-, we have decided to include it in the inventory because displacement is an essential behavior in social robots. Displacement supports the difference between animate and inanimate entities and shows up to be very compelling for children and a powerful way to attire their attention and engage them in interaction. Furthermore, the capability of displacing autonomously is a core requisite for mimicking or evoking dog or cat-like contingent responses.

Social behaviors category is subdivided according to functionality into *Attention seeking, Feeding-related, Affection-related, Play and Gestures* subcategories.

Finally, Pleo's wide repertoire of vocalizations convey recognizable emotionality, modifying and making sense of movements and postures, expressing internal states, acting as a cues and feedback and enhancing life-likeness, pet-likeness and baby-likeness. We have not grouped vocalizations in independent categories but we have included them according to their specific *meaning* or function into different behavior categories. Therefore, in the category *Attention* *seeking* we included two kinds of vocalizations: *Calls* and *Agonistic*. In *Feeding Related* category, *Chew* and *Belch* and in *Affection related* category *Purr*.

It is interesting to note that there are very scarce references to Pleo's sounds beyond a general reference to their plaintive utterances that were reported to be distressful for some users in the ethnographic study of Fernaeus (Fernaeus et al., 2010). The only detailed description of Pleo vocalizations in literature –as long as we know- is in Rosenthal experimental study on empathy, were Pleo's vocalizations were regarded as a very powerful means to convey the expression of suffering in the condition where the participant watched a video of Pleo being tortured and another one of Pleo been stroked gently [24]. The reported sounds from Pleo indicating that it was suffering, was crying and bawling, rattling breath, choking and coughing. The sounds of satisfaction were purring, singing, squealing with glee, chewing (while being fed) and curious babbling (Rosenthal-von der Pütten et al., 2013).

4.4.2. Inventory

Table 4-5 Pleo's behavior categories and behavioral units

1. SPONTANEUS ACTIVITY

1.1. Not social
- 1.1.1. **Locomotion**
  - 1.1.1.1.Walk Ahead
  - 1.1.1.2.Walk Backwards
  - 1.1.1.3. Displacement

1.2. Social
- 1.2.1 **Attention seeking**
  - 1.2.1.1. Agitation
  - 1.2.1.2. Funny movements
  - 1.2.1.3. Orient/Gaze
  - 1.2.1.4. Calls
  - 1.2.1.5. Agonistic
- 1.2.2. **Feeding-related**
  - 1.2.2.1. Open mouth
  - 1.2.2.2. Take/Mouth
  - 1.2.2.3. Chew
  - 1.2.2.4. Belch
  - 1.2.2.5. Release
  - 1.2.2.6. Refuse
- 1.2.3. **Affection-related**
  - 1.2.3.1. Snuggle

[24] https://www.youtube.com/watch?v=wAVtkh0mL20

1.2.3.2. Calm down
1.2.3.3. Purr
1.2.3.4. Nap

1.2.4. **Play**

1.2.4.1. Invitation to Play
1.2.4.2.Tug

1.2.5. **Gestures**

1.2.5.1. Nod
1.2.5.2. Shake Head
1.2.5.3. Squint
1.2.5.4. Instant Freeze
1.2.5.5. Bow
1.2.5.5. Cringe

2. INACTIVITY

2.1. Asleep/Collapsed

2.2. Turned off

3. ACTIVATED PERFORMANCE

3.1. Tricks

3.1.1. **Balance**
3.1.2. **Sit down**
3.1.3. **Burst of laughing**
3.1.4. **Faint**

3.2.Learned behavior

3.2.1. **Bow**
3.2.2. **Come**
3.2.3. **Sing**
3.2.4. **Count**

3.3. Turned On-Off

3.3.1. **On**
3.3.2. **Off**

Table 4-6 Pleo's behavior categories and behavior units descriptions

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1. SPONTANEOUS ACTIVITY: Pleo moves or displaces, or hold a posture with perceptive orientation, while it is not asleep nor collapsed (see *Collapsed*) nor turned off (see *Turned Off*).

1.1. No social

1.1.1. **Locomotion** Sequence in which the robot displace the body from one point to another of the exhibit horizontally **(Fig. 4-6)**

1.1.1.1. **Walk Ahead** Coordinated movement of the four legs that displaces Pleo forwards

1.1.1.2. **Walk Backwards** Coordinated movement of the four legs that displaces Pleo backwards

1.1.1.3 **Displacement** Pleo's short and erratic displacements from one place to another as a result of legs movements other than walking that seldom results in a noticeable change in the relative position and/or distance to other elements in the interactional space (i.e. child, furniture, toys) that eventually is noticed by users and interpreted as an intentional displacement (e.g. approach).

1.2. Social Any Pleo's interactive behavior that communicates intent, needs, expresses emotions or internal states, often interpreted as an attempt to obtain a reaction from the user (e.g. begging for food) as providing material or affective resources (i.e. giving attention or affection). This behavior is communicative in essence and can be addressed to obtain an emotional (e.g. amusement, concern) or behavioral response (e.g. feeding) from the user as a part of a social exchange (e.g. mouthing the piece of food presented).

1.2.1 **Attention seeking** Et-epimeletic behavior to catch users' attention –interpreted as- to obtain resources as affection or food or engage in interaction or play.

1.2.1.1. **Agitation** Quick change of postures or rapid and repeated movements of limbs and body segments (e.g. raising and lowering the head or turning it side to side) while Pleo **s**tands up (i.e. four limbs fully extended on the ground) and bends down (i.e. flexing the front leg/s outwards projecting the kneels to the floor) and tail.
(Fig. 4-7)

1.2.1.2. **Funny movements** Pleo's bioinspired movements of a body segment or limb that seems to convey emotion or intent like quivering the tail or raising one leg like to shake hands.

Tail: Moves the tail vertically repeatedly or side to side, vibrates the tail while raised or quiver only the tail's tip.
(Fig. 4-8)

Legs*:* With four limbs fully extended on the ground raises and maintains only one front or hind leg suspended and flexed outwards **(Fig. 4-9)**.

Eyes: Pleo blinks, opening and closing the eyes rapidly and repeatedly as in attention or affection
(Fig. 4-10)

1.2.1.3. **Orient/ Gaze** Pleo turns the head towards sb/sth followed by a pause as if staring. Different from *Agitation* in the pause after the head rotation.

1.2.1.4. **Calls** Vocalizations that can be interpreted by the user as calls or intents to attention getting (i.e. begging for food) and recalls bioinspired vocalizations in distress or affliction or on the contrary, expressing content or an amiable disposition. Vocalizations that are interpreted as aggressive are considered into the category *Agonistic.*

Distress/Affliction Bioinspired pitiful or complaintive vocalizations as if from physical or mental suffering, such as moan (i.e. prolonged low, inarticulate sound); grumble (i.e. murmur or mutter in discontent or unhappiness); groan (i.e. deep, guttural mournful sound characteristic of a hog or a bear); yell (i.e. scream with pain or fright); choke (i.e. sound like to suffer from or as from strangling or suffocating).

Friendly Includes interrogative vocalizations that go up at the end; melodic, vocalization that follows melodic and rhythmic patterns (i.e. like a gentle owl's call *Uh! Uh! Uh!*) and other pleasant or aimable sounds.

1.2.1.5. **Agonistic** ***Threat Display*** Pleo stands up with head and tail raised with an open mouth and shake tail and head accompanied by a roar, a loud, long, deep cry or howl as in anger, different from any other Pleo's vocalization.

1.2.2. **Feeding-related** **(Fig. 4-11)**

1.2.2.1. **Open mouth** Separated jaws while the head is kept upward

1.2.2.2. **Take/Mouth** Press jaws and keep a piece of food or gadget in between them, suspended.

1.2.2.3. **Chew** As if the audibly sound of chewing with vigorous working of the jaws as munching.

1.2.2.4. **Belch** The sound of an eruct (ejecting gas spasmodically and noisily from the stomach through the mouth).

1.2.2.5. **Release** Pleo's separates the jaws while the head is downwards. It is typically observed after bite to release/drop something that is mouthing as if placing it on the ground.

1.2.3. **Affection-related**

1.2.3.1. **Snuggle** **Nestle** Pleo huddles up to the user's chest or stomach (i.e. cuddle) while being hugged placing the body close in contact with the user flexing the legs allowing full contact with the body while slowing down the movements and getting quiet and calm eventually closing the eyes and purring stopping any opposing force to the grasp.

Press Pleo draws or press a part of the body -mainly the chin- when gentle scratched or rubber, as cats do in willingness to close up or prolong the physical contact as for comfort of from affection, often accompanied by closing the eyes, as in content.

1.2.3.2.	**Calm down**	The movements slow down when in a state of agitation Pleo is given some gently physical contact and/or is fed.
1.2.3.3.	**Purr**	Low, continuous rhythmical tone. Repetitive, buzz-like, soft murmuring sound characteristic of cats expressing friendliness or pleasure when they are especially comfortable. Similar as well to doves cooing.
1.2.3.4.	**Nap**	Pleo closes the eyes, calm down when in close contact with somebody hug or embrace and seems sleepy or very content/pleased. Sometimes is followed by a vocalization like snoring or purring.

1.2.4. **Play**

1.2.4.1.	**Invitation to Play**	Front legs and front part of the body to the floor, while the bottom and tail are upwards, mouth open and making and excited sound like panting like dogs in intense eagerness **(Fig. 4-12)**
1.2.4.2.	**Tug**	In the posture of *Invitation to Play*, Pleo mouth tightly an object and dispute it to the user that pulls.

1.2.5. **Gestures**

1.2.5.1.	**Nod**	Pleo makes repeatedly slight, quick downward bending forward of the head as assenting
1.2.5.2.	**Shake Head**	Pleo moves the head side to side quickly and repeatedly as in denial, refusal or disapproval.
1.2.5.3.	**Squint**	Pleo's eye lids are half closed, showing just a piece of Pleo's iris as if looking downwards, with pleasure or sleep.
1.2.5.4.	**Instant Freeze**	Suddenly Pleo becomes immobile, ceases all movement for a (brief) moment.
1.2.5.5.	**Bow**	Pleo inclines the head, lowers his front end, elbows close to or touching the ground, while keeping his back end up)
1.2.5.6.	**Cringe**	Pleo crouches the body close to the ground, lower the head to one back side, close the eyes, all four legs bent and the belly is raised slightly off of the ground as in fear, withdrawal or servility. **(Fig. 4-13)**

2. INACTIVITY

2.1. Asleep	Pleos crouches, collapses, freezes and stop permanently.
2.2. Turned off	From active mode, when the on-off button is pressed, Pleo freezes standing in four legs extended and head raised even and suddenly close the eyes and beeps.

3. ACTIVATED PERFORMANCE Pleo's performances that appear only after a specific ritualized manipulation that cannot be considered bio-inspired or intuitive because it is not possible for partners to come out without help or specific training. These behaviors do not belong to the bio-inspired *natural* Pleo's repertoire.

3.1. Tricks Behaviors triggered by a specific manipulation or protocol performed by a trained partner in a stimuli-response base without requiring previous learning process by the side of the robot but need to be learned by the partner. The particular behavior is exhibited deterministically –except malfunction- every time the conditions are present.

3.1.1. **Balance** Standing with its head upwards the tail down raises its right anterior pow and the left hide leg extended outwards at the same time and stand still on the other two opposite limbs contact with the ground and a s triumphant vocalization is uttered *ta-dah!* **(Fig. 4-14)**

3.1.2. **Sit down*** Pleo is in upright position, with the hind legs extended and resting with the bottom on the ground, while front legs are extended and straight.

3.1.3. **Burst of laughing** Sudden utterance of sounds like human loud burst of sound to a series of quiet chuckles and is accompanied by open mouth and bowing and agitating the head up and down and side to side **(Fig. 4-15)**

3.1.4**. Faint*** In this posture, the body is in a lateral recumbent, prostrate position, primarily the left or right side of the torso is on resting surface, the four legs extended outwards.

3.2. Learned behavior Behavior pattern triggered by a specific verbal command after a training ritual (i.e. involving the *learning stones*) performed with Pleo by a trained partner. Require previous learning process and a particular Pleo state (attention). It is exhibited in the bases of stimuli-response, deterministic mode, if all the conditions are present and after a non-intuitive rigid training protocol requiring the use of particular gadgets.

3.2.1. **Bow** Bend both legs, incline the head, lowers his front end, elbows close to or touching the ground, while keeping his back end up.

3.2.2. **Come** Walks ahead when beckoned.

3.2.3. **Sing*** Sings a song

3.2.4. **Count*** Count numbers

3.3. Turned On-Off

3.3.1.On
3.3.2.Off

---

*Not seen by the author, but reported in literature

a)

b)

c)

d)

e)

f)

Figure 4-6 Non Social > Locomotion
a) to f) Walking ahead sequence

a)

b)

c)

d)

e)

f)

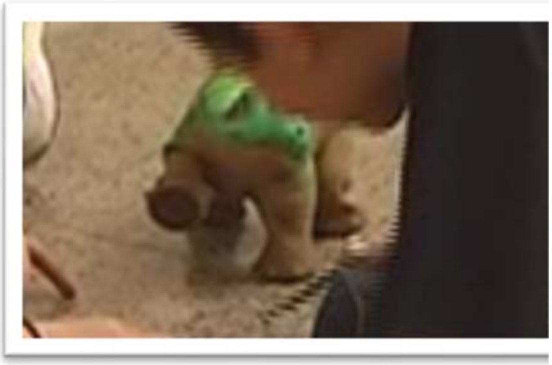
Figure 4-7 Social >Attention Seeking > Agitation

a) b)

a) b)

c) d)

Figure 4-8 Social > Attention Seeking > Funny movements > Tail
a) and b) up and down, c) to f) side to side



a)

b)

Figure 4-9 Social > Attention Seeking > Funny movements > Legs

a)

b)

c)

d)

e)

f)

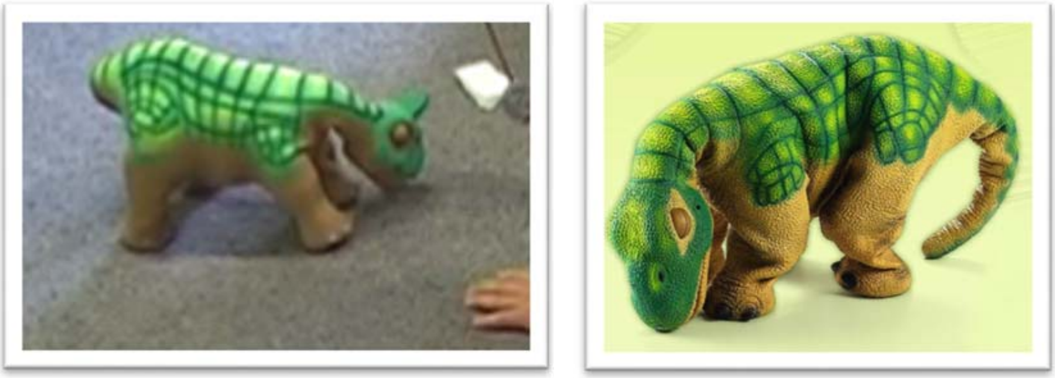
Figure 4-10 Social > Attention Seeking > Funny Movements > Eyes
a) to f) Blink

a) b)

c) d)

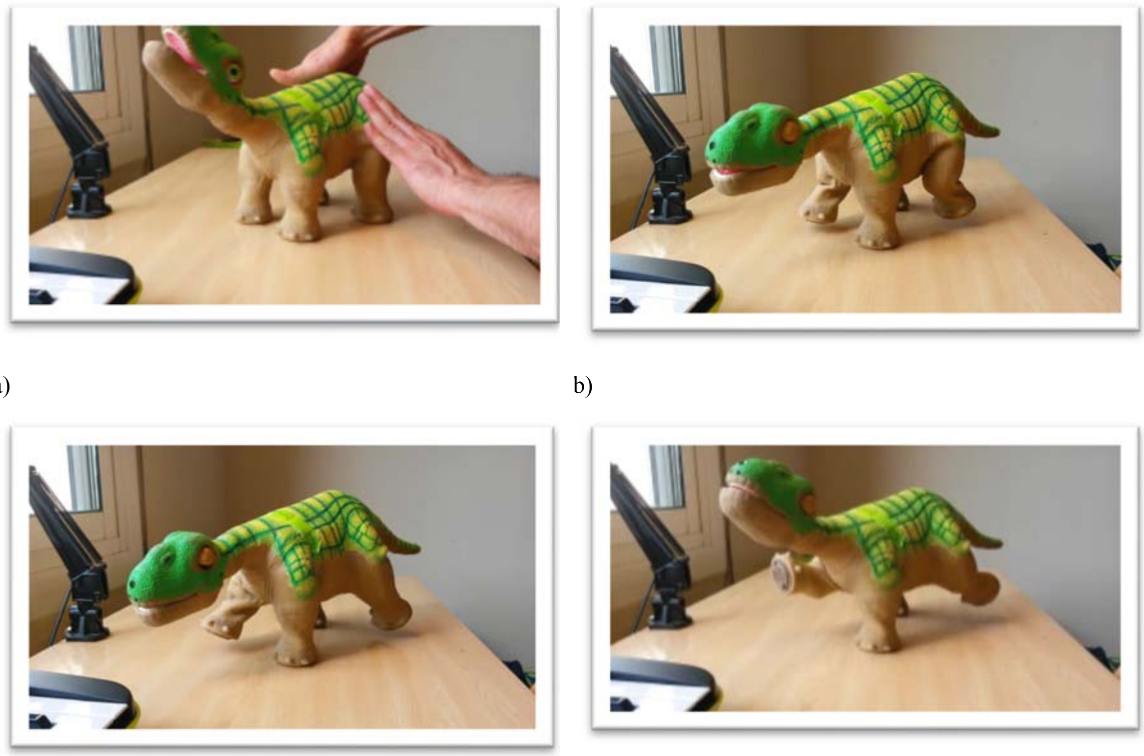
Figure 4-11 Social > Feeding-related
a) Open Mouth, b) and c) Take/Mouth, d) Release

Figure 4-12 Social > Play > Invitation to play



e) f)

Figure 4-13 Social > Gestures > Cringe



a) b)

c) d)

Figure 4-14 Trick > Balance
a)activation, b) to d) display

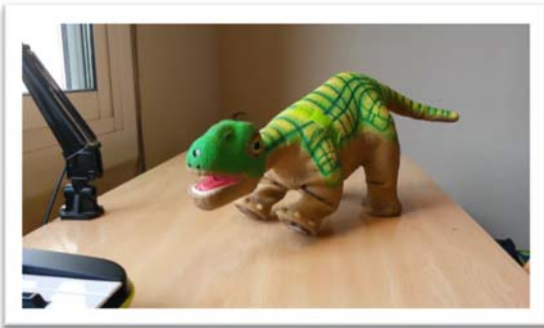
a)

b)

c)

d)

e)



f)

Figure 4-15 Trick > Burst of laughing
a)activation, b) to f) display

4.5. Children's Behavior towards Pleo Ethogram

This theoretically and empirically grounded inventory systemizes children's behaviors interacting with Pleo in a situation of free unstructured play. The system focus on the *interactional surface* of behavior and the emphasis is given on functionality (i.e. care giving, exploring) rather than on the morphology or structure of the behaviors (i.e. movements and positioning).

This inventory is derived from literature (see *4.5.1.Antecedents*) and also empirically from the observational data gathered in previous studies in the wild and in the lab (see Table 4-1 and 4-2). The inventory has been tested on new video-recorded material of episodes of free play whose results are discussed in Section 4-7.

Even though the psychological state of children (i.e. mood, emotions) during interaction is a very relevant variable, we do not include this dimension within the inventory. Coding emotional states would incorporate a higher level of interpretation than the rest of observable interactive behaviors in our system. In addition, children facial expressions are seldom difficult to distinguish and sometimes are not observable from the observer's position, due to the dynamics of children when playing freely with Pleo and the constrains of the setting (see Section 4.5.4.).

The rest of this section is structured as follows: in the first subsection the more interesting antecedents of behavior catalogues used to describe and measure children's interactive behavior with social robots are summarized in tables (Tables 4-7 to 4-10) and briefly discussed. Secondly, the categorization criteria are elaborated and discussed. Thirdly the ethogram is first presented in a summary table (Table 4-12) and afterwards the behaviors are described with the rules of coding, when required, to facilitate the register and coding (Table 4-13). The descriptions are followed by some photographic examples of the specific actions from the videos obtained in our studies on children interacting with Pleo (Figures 4-14 to 4-23).

4.5.1. Antecedents

In 2002 Dautenhahn reported a comparative observational study with children with ASD interacting with a mobile robot -without specific resources for interacting socially- and with a toy truck. The research had a methodological focus and discussed the multimethod approach for analyzing the interaction and communication of children with autism. This position is founded on "the belief that different quantitative and qualitative analysis techniques are necessary to fully assess and appreciate the communication and interaction competencies of children with autism" and thus to inform robots' design (K Dautenhahn et al., 2002). The trials were carried out in an experimental setting that also involved adults. The observational data were analyzed using a set of fourteen criteria, broken into two general categories, Action/Behavior and Verbal. The first category consists of eye gaze, eye contact, operate, handling, touch, approach, move away and attention. The second category consists of vocalization, speech, verbal stereotype and repetition and the analyses proposed was conversational analyses (Table 4-7). Unfortunately, only preliminary results on eye gaze from the Action/Behavior category were reported

Table 4-7 Categories system to measure children with autism's behavior towards a mobile robot (K Dautenhahn et al., 2002)

Categories	Behavior	Definition and Examples
I Action/Behavior	Eye Gaze	Direction of gaze
	Eye Contact	Child making eye contact with a person, gazing at the front of the toy truck, or the heat sensor of the robot which has an "eye-like" appearance
	Operate	Manipulating an object to make it work, e.g. an IR sensor in order to control the robot
	Handling	Picking up, pushing, etc. Includes an element of inquisitiveness, including pressing buttons
	Touch	Physical contact, child initiated
	Approach	Moving towards. Must be a deliberate movement
	Move Away	Must be a deliberate movement away from object
II Verbal	Vocalization	Sounds such as yells, mumbling, including whistling (start of vocalization)
	Speech	Word utterances, not necessarily coherent, but a string of words (start of speech)
	Verbal Stereo	Echolalia, non-speech sounds with repetition or without clear purpose
	Repetition	Any behavior or action which can be grouped and sections repeated, specifically "autistic behaviors" such as spinning wheels or other distinct repetitive behaviors that autistic children often show
	Attention	The apparent focus of the child's attention, e.g. robot or toy truck
Other	Other	Actions that are as yet unclassified, or notes (for example reactions/interactions to people, distress/boredom of child, symbolic play such as stories/play, etc.)
	Blank	No or very little visible child action or introspective behavior without external purpose, e.g. sitting almost motionless

Kahn's (Kahn, Jr. et al., 2006) comparison study between interactive behavior towards the pet-robot AIBO and towards a stuffed dog focused on reasoning and behavioral interaction. They studied children's conceptions of biological entities and their robotic counterparts, from a developmental perspective. The research question was whether children act and think of a robotic pet as if it was alive, and if these behaviors and cognitions changed over time. For the intra-subject design they constructed a categories system of 6 overarching categories to measure and compare how children behave towards the robotic pet AIBO and a stuffed dog with an emphasis on social agency and moral standing attributions (Table 4-8).

Table 4-8 Coding categories of children's interactions with robotic-dog AIBO and a stuffed dog (Kahn, Jr. et al., 2006)

Behavioral Category		**Definition and Examples**
1. Exploration	Anatomy Check Touch limbs Demonstrate Feed	Reference to the child's visual or tactile exploration, manipulation, inspection, pointing, and feeding of the artifact. E.g. child explains to the interviewer that AIBO is a boy while inspecting the hindquarters of AIBO.
2. Apprehension	Startle Wariness	Reference to the child' exhibiting a startle response, wariness, or other intentional movement away from the artifact. E.g. AIBO stands and child backs away quickly
3. Affection	Non-exploratory Touch Pet Scratch Kiss Embrace Verbal	Reference to the child engaging in petting, scratching, kissing, carrying, embracing and one-way verbal greetings to the artifact. E.g. child squeezes the stuffed dog in a big hug.
4. Mistreatment	Rough handling Thumping Throwing	Reference to the child's behavior showing disregard for the artifact, including rough handling (e.g. hitting, squishing) and throwing. E.g. child swings the stuffed dog overhead and then thumps it to the floor.
5. Endow Animation	Vocalize Movement Object Play Feed	Reference to the child enlivening the artifact in order to perform a behavior or action with it, including making sounds and moving the artifact around. E.g. child throws the bone and says "Fetch!" Then child picks up the stuffed dog and begins to hop it toward the toy.
6.Attempt to reciprocity	Motion Verbal Offering	Reference to the child's behavior not only responding to the artifact, but expecting the artifact to respond in kind based on the child's motioning behavior, verbal directive, or offering. E.g. AIBO is searching for a ball. Child observes AIBO's behavior and puts the ball in front of AIBO and says, *Come get it*

According to Kahn's findings and methodology, Melson carried out another comparison study to investigate the reasoning about and interactions with the robotic pet AIBO and a live dog, an Australian Shepherd (Melson, Kahn, Beck, Friedman, et al., 2009). From a development perspective, Melson's cross-sectional study covered children from 7 to 15 years old. To study children interactive behavior they proposed a coding scheme with three categories for social behavior -social touch, verbal engagement and attempts at reciprocity-, another category for children exploration of the robot as an artifact and the third one to measure the distance during interaction (Table 4-9).

Table 4-9 Coding scheme of children's behaviors toward a robot dog and a live dog (Melson, Kahn, Beck, Friedman, et al., 2009)

Behavior	**Definition and Examples**
Exploration as artifact	Instances of treating the target dog as an artifact or machine (e.g. poking, shaking)
Affection	Instances of affection (e.g. hugging, petting kissing stroking)
Attempts at reciprocity	Attempts at (to engage it in) reciprocal interaction (e.g. offering a ball, talking to, motioning to), verbal attempts, such as commands (e.g. *Come!*) or questions (*Do you want to play?*)
Apprehension	Weariness

For systematic observation of children's behavior with Pleo our research team constructed and applied a coding scheme inspired in Kahn's and Melson's works adapted to our research focus on children perception of social agency, investigating both children's interactive behavior and their judgements and reasoning. Table 4-10 presents the overarching categories and the behavioral units along with a tentative correspondence with Kahn's categorization (Table 4-8). Only *Physical contact, Gaze, Grooming* and *Show Something* were coded and analyzed (highlighted in the Table 4-10) (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012).

Table 4-10 Coding scheme for children's behaviors toward Pleo during free play in pairs (Heerink, M.et al, 2012)

Category	Behavior	Analytic Category
Emotions	Enjoyment	
	Boredom	
	Frustration	
	Neutral	
	Fear	IV Apprehension
Verbal	Vocalization	
	Speak to Pleo	II Attempt at reciprocity
	Speak to play-mate	
	Speak to adult	
	Speak (other)	
Distance	Within their grasp	
	Beyond their grasp	
Physical contact	Lift up	III Exploring as artifact / I Affection
	Hug	I Affection
	Pad	I Affection
	Stroke	I Affection
	Let down	I Affection
	Hold by the tail	I Affection (negative)
	Hit	I Affection (negative)
	Handle	III Exploring as artifact
	Manipulation	III Exploring as artifact
Gaze	Look at Pleo's area	Orientation to interaction
	Look at other	Orientation others
	Look at adult	
	Eye-contact Pleo	
Other Interactive behavior	Show something	II Attempt at reciprocity
	Grooming	I Affection

Note. Only the shaded units were analyzed in the cited study.

In addition to the antecedent interactive systems to measure interaction between children and social robots, we cite here the coding scheme elaborated and applied by Millot (Millot et al., 1988) to study systematically children's interaction with dogs. He proposed three overarching categories applicable to group children and dogs' behaviors: *Threaten and aggression*, *Appeasing and liking* and *Retreating*. It is to notice that the authors excluded explicitly the feeding behaviors. We consider that this attempt to analyze simultaneously both child and dog behavior in the course of the interaction is the most inspiring way to conceptualize and measure the interactive behavior of a child and a pet dyad, analyzing the contingences between antecedent and subsequent behaviors, taking child and dog both as emitters and receivers.

Table 4-11 Coding scheme of child and dog interactive behaviors (Millot et al., 1988)

Categories	Behaviors	
	Children	**Dog**
I Threaten and aggression	Threatening the dog	Biting, trying to bite
	Hitting the dog	Barking, growling
	Vigorously throwing an object at the dog	
	Pushing the dog away with arms or legs	
	Pulling the dog's tail, hair or paw	
II Appeasing and liking	Patting the dog	Approaching the child
	Putting the hand on the dog	Putting its muzzle
	Leaning, squatting or lying beside the dog	Sniffing, taking an object presented or given by the child
	Stroking the dog	Giving an object grasped or solicited by the child
	Kissing-or hugging the dog	
	Giving an object to the dog	
	Non-verbal soliciting	
	Calling or speaking to the dog	
III Retreating	Retreating patterns	Retreating patterns

4.5.2. Categorization Criteria

Inspired by Kahn's model (Kahn, Friedman, Freier, & Severson, 2003, 18) and according to the theoretical assumptions and our previous work, the catalog of children's interactive behavior is separated into two main sections *Handle as an Artifact* and *Social Interaction,* separation based on the degree of *socialness* involved in the intentional behavior towards the robot (Table 4-11) (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012).

Handle as an artifact encompasses child's inquisitive behaviors of visual (*Exploration)*- and tactile-manipulative (*Manipulation*) investigation, putting objects in and out Pleo's mouth *(Put in the Mouth, Take from the Mouth),* moving the robot from one place to another (*Displace*) as well as rough behaviors towards Pleo (*Rough Manipulation*). Finally one container unit was added to code other kind of no-rough and no-inquisitive tinkering of the robot without displacement (*Other*).

Social Interaction includes children's affiliative (e.g. petting, kissing) and no affiliative behaviors (e.g. hitting) with or towards Pleo conveying a social emphasis and implying –to some extend- the attribution to the robot of the subjective entity of a living creature.

Social Interaction is separated in sub-sections based on the valence (attraction vs. aversion) of the rapport shown (i.e. affiliative or pro-social vs not conflict or agonistic behaviors). The sub-categories are *Giving affection* and *Attempt to reciprocity*-

According to the intimacy axis, *Giving affection* is subdivided in turn into two categories: *Substantial contact* (i.e. physical contact with children's chest, head or stomach), *Other Contact* (i.e. physical contact with hands and fingers) and *Affectionate talk*, nice and pleasant verbal behavior addressed to Pleo (e.g. baby-talk).

Attempts at reciprocity are affiliative behaviors that tend to obtain a contingent behavior from Pleo. They are social bids addressed to engage Pleo in reciprocal interchanges mainly in providing resources (e.g. feeding), attending its needs or playing. *Attempts at reciprocity* imply not just responding to the robot actions but expecting the robot to respond in kind based on the previous motioning behavior, verbal directive or offering (Kahn, Jr. et al., 2006). *Attempts at reciprocity* is a central concept in our model as long as are expressions of children's theory of Pleo's mind, their expectancies on Pleo's capabilities and, in general, of the illusion of pet-likeness (i.e. show a ball and roll it up in the believe that maybe Pleo is going to engage in a catch and fetch play). This category encompasses 6 subcategories: *Attention seeking, Present, Offer, Feed, Cuddle and Social Bids.*

The category *Agonistic* includes all behaviors showing disregard or even aggressive and punitive behaviors towards Pleo (*Hit* and *Mistreat*) and withdrawal behaviors (*Defense*).

4.5.3. Inventory

Table 4-12 Children's interactive behaviors towards Pleo. Categories, subcategories and behavior units

1. **ENGAGEMENT**

    1.1. Handle as an artifact

    1.1.1. **Exploration**

    1.1.2. **Manipulation**

    1.1.3. **Handling**

    1.1.3.1. Mouth

    .
    1.1.3.1.1. Put in the mouth
    1.1.3.1.2. Take from the mouth

    1.1.3.2. Other

    1.1.3.3. Displace

    1.1.4. **Rough Manipulation**

    1.2. Social interaction

    1.2.1. **Giving Affection**

    1.2.1.1. Substantial Contact

    1.2.1.1.1. Press to bosom
    1.2.1.1.2. In Lap
    1.2.1.1.3. Hug
    1.2.1.1.4. Carry

    1.2.1.2. Contact Other

    1.2.1.2.1 Pet
    1.2.1.2.2. Kiss
    1.2.1.2.3. Groom
    1.2.1.2.4. Touch

    1.2.1.3. Affectionate talk

    1.2.2. **Attempts at reciprocity**

    1.2.2.1. Attention seeking
    1.2.2.2. Present
    1.2.2.3. Offer
    1.2.2.4. Feed
    1.2.2.5. Cuddle
    1.2.2.6. Social Bids

    1.2.3.. **Agonistic**

    1.2.3.1. Aggression

    1.2.3.1. 1. Hit
    1.2.3.1. 2. Mistreat
    1.2.3.2. Defense

    1.3. Attentiveness

2. **DISENGAGEMENT**

    2.1. Refuse Interaction

    2.2. No Interaction

Table 4-13 Children's interactive behaviors towards Pleo description

1. ENGAGEMENT

1.1. Handle as an artifact **(Fig. 4-16)**

1.1.1. **Exploration** Without physical contact the child visually examines carefully the Pleo's body or performance. Is a visual inspection observing and checking that implies an element of inquisitiveness. Differs from look at behavior because a postural adaptation to better observe is performed.

1.1.2. **Manipulation** Manipulation of the robot as touching, pushing or moving parts of Pleo's body. Handling in order to allow the child checking, inspecting or observing more thoroughly or to explore with their actions Pleo's functionalities or responses without social meaning (e.g. turn on/off, open the batteries tap). Not necessarily implies physical contact (e.g. passing the hand before the nose's sensor).

1.1.3. **Handling** Physical manipulation, without the sense of inquisitiveness with contact with fingers or hands at any part of Pleo body, as touching (i.e. contact with fingers or hands any part of Pleo body), poking (i.e. prod or push with the finger or something narrow or pointed like a *learning stone*); pinch (i.e. squeeze or compress between the finger and thumb).

1.1.3.1. **Mouth** Actions related to Pleo's capabilities of opening the mouth and taking it and keeping between the jaws.

. 1.1.3.1.1. **Put in the mouth** Introduce objects or a finger between Pleo's jaws

1.1.3.1.2. **Take from the mouth** Remove and object or finger from Pleo's mouth while Pleo is mouthing it, like taking it from it.

1.1.3.2. **Displace** Actions on Pleo that results in ostensible displacement (e.g. pull, push)

1.1.3.3. **Other** Physical manipulation not involving mouthing nor displacement

1.1.4. **Rough Manipulation** Brusque physical manipulation or handling, misuse with disregard of possible damage (e.g. separating forcefully Pleo's jaws).

1.2. Social Interaction

1.2.1. **Giving Affection** Child's actions towards Pleo addressed to content it, to influence its mood or wellbeing, to give it pleasure or to make it feel good with or without physical contact, regarding or treating Pleo as an object of affection.

1.2.1.1. **Substantial Contact** Actions that implies close contact with child's chest, stomach, lap, legs, arms or shoulders. The most intimate behavior is maintaining Pleo stomach with stomach.

1.2.1.1.1. **Press to bosom** Pleo is hold against the child's body, totally suspended and pressed tightly to his/her chest, stomach, shoulder or neck.
(Fig. 4-17)

1.2.1.1.2. **In Lap** Pleo is lifted and placed in the child's lap or legs. **(Fig. 4-18)**

1.2.1.1.3. **Hug** One or both arms around Pleo's body the child clasps it tightly with the arms, embraces, and wraps by the arms, without lifting it from the ground or surface where is placed. While hugged Pleo may be hold on the child's lap or elsewhere as in other's lap, on the floor or on a table. If there is full contact between child's and Pleo's body then the behavior is considered *Press to bosom*

1.2.1.1.4. **Carry** Pleo is picked up, supported and transported to another place by holding in the arms (different from pushing away). **(Fig. 4-18)**

1.2.1.2. **Contact Other** Affectionate physical contact with fingers, hands or face. **(Fig. 4-19)**

1.2.1.2.1 **Pet** Touch lovingly, affectionately or tenderly as caressing (i.e. with the pads of fingers, palm of hand, back of the hand, moves along back and forth in continuous contact on back, tail, top of head), scratching (i.e. using fingertips or fingernails to gently rub the chin, particularly where the jawbone connects to the skull), padding/tapping (i.e. strike lightly or gently (repeatedly) with something flat, as with a paddle or the palm of the hand on back, tail, top of head). **(Fig. 4-20)**

1.2.1.2.2. **Kiss** Contact Pleo with the lips or any other part of the face/head as cheek, forehead or chin. **(Fig. 4-21)**

1.2.1.2.3. **Groom** The child puts Pleo on dresses or ornaments, makes Pleo neat or tidy. Cleaning, brushing, removing pieces of dust, and any other manipulation that tend to improve Pleo's looks and tidiness. **(Fig. 4-22)**

1.2.1.2.4. **Touch** Other gentle touch or manipulation with physical contact with any part of Pleo's body, such as hold (i.e. exert pressure with the fingers of one hand or with two hands) to make Pleo look at you. **Fig. 4-23)**

1.2.1.3. **Affectionate talk** Child addresses Pleo in a monologue in a nice or gentle way, seldom using baby-talk, asking questions, appreciative remarks, soothing speaking.

1.2.2. **Attempts at reciprocity** Socially interactive behaviors of reciprocal nature, in which the child expect a response, a reciprocal interaction. The child not only responds to the artifact, but expects the artifact to respond based on their behavior, verbal directive, or offering (e.g. Pleo walks ahead, child observes Pleo's behavior and puts a piece of food in front of Pleo and says *Come, get it*). **(Fig. 4-24)**

1.2.2.1. **Attention seeking** With or without physical contact the child attempts to getting the attention or awaking Pleo. When there is physical contact (i.e. hitting or shaking Pleo) it should be gentle and amiable if not the behavior is considered *Mistreat.* Other attention seeking behaviors are snap fingers, wave, whistle, clap hands, bang on the table or on the floor.

1.2.2.2. **Present** Bring an object, part of the body close to Pleo's eyes, mouth, nose or chin as showing it to Pleo as expecting it detects it and responds consequently.

1.2.2.3. **Offer** Present a piece of food or any object (or a part of the body) close to Pleo's face (i.e. mouth, cheek, eyes) while looking at Pleo and maintain this position for more than 2 seconds or until Pleo takes it.

1.2.2.4 **Feed** Put a piece of food or any object between Pleo's jaws after the behavior of *Offer*

1.2.2.5. **Cuddle** Hold Pleo with full contact of Pleo's stomach to partner's stomach/ chest/shoulder as expecting Pleo's to nestle and/or calm down and/or fall asleep.

1.2.2.6 **Social Bids** Use the arms, hands, and/or fingers or verbal utterances or a combination to communicate and order, direction, request as expecting a contingent response from Pleo based on conventional social exchanges – interpersonal and with pets- as waving hello, greeting, showing numbers with fingers, waving goodbye, pointing, beckoning.

1.2.3. **Agonistic** Child's behaviors treating Pleo roughly, badly or abusively with disregard to possible damage or even with the intention to harm/damage it (e.g. hitting, squishing throwing). Implies violence, punitive intention, aggressiveness.

1.2.3.1. **Aggression (Fig. 4-25)**

1.2.3.1.1. **Hit** Deal a blow or stroke to any part of Pleo's body deliberately with fingers or hands or with an object (e.g. *learning stone*).

1.2.3.1.2 **Mistreat** Any other action that implies violence as force feeding (i.e. separate Pleo's jaws by force or even violence while putting into an object or pushing an object into the mouth), held by the tail (i.e. Pleo totally suspended by the tail and eventually shaken), force or immobilize (i.e. restrain or restrict Pleo's movements grasping by force or holding it tight or with violence), throw (i.e. the child forcefully flings Pleo through the air, but not just a simple drop).

1.2.3.2. **Defense** Actions of avoidance and withdrawal ranging from simply startling or leaning away from Pleo to getting up and leaving.

1.3. Attentiveness — Without taking part in the interaction, the child looks at Pleo, Pleo's stuff or at someone who interacts with Pleo, and/or talks about Pleo.

2. DISENGAGEMENT

2.1. Refuse to Interact — Child is either passively non-responsive or actively declines interaction with Pleo.

2.2. No interaction — Inactivity, inattentiveness, attention focused in other things or event, engaged in other activity or objects.

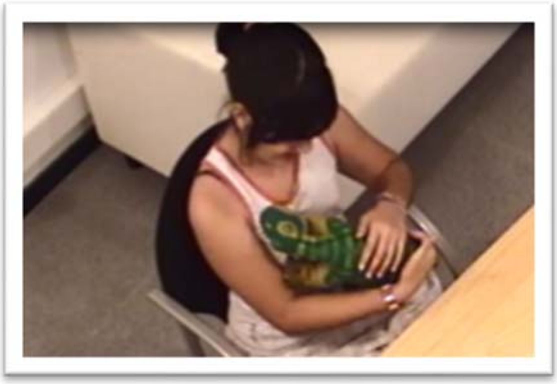
a)

b)

c)

d)

Figure 4-16 Handle as an artifact
a) Exploration, b) to d) Manipulation



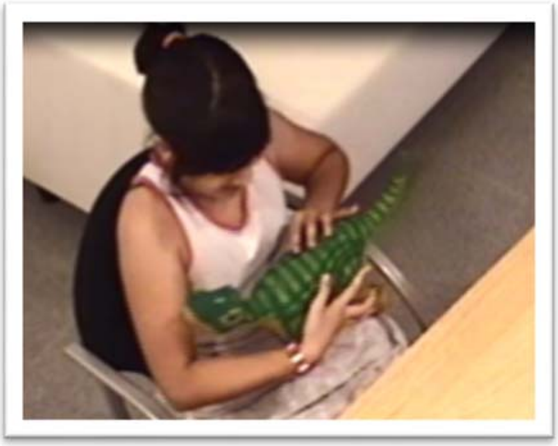
a)

b)

c)

d)

Figure 4-17 Giving Affection > Substantial contact
a) to d) Press to the bosom

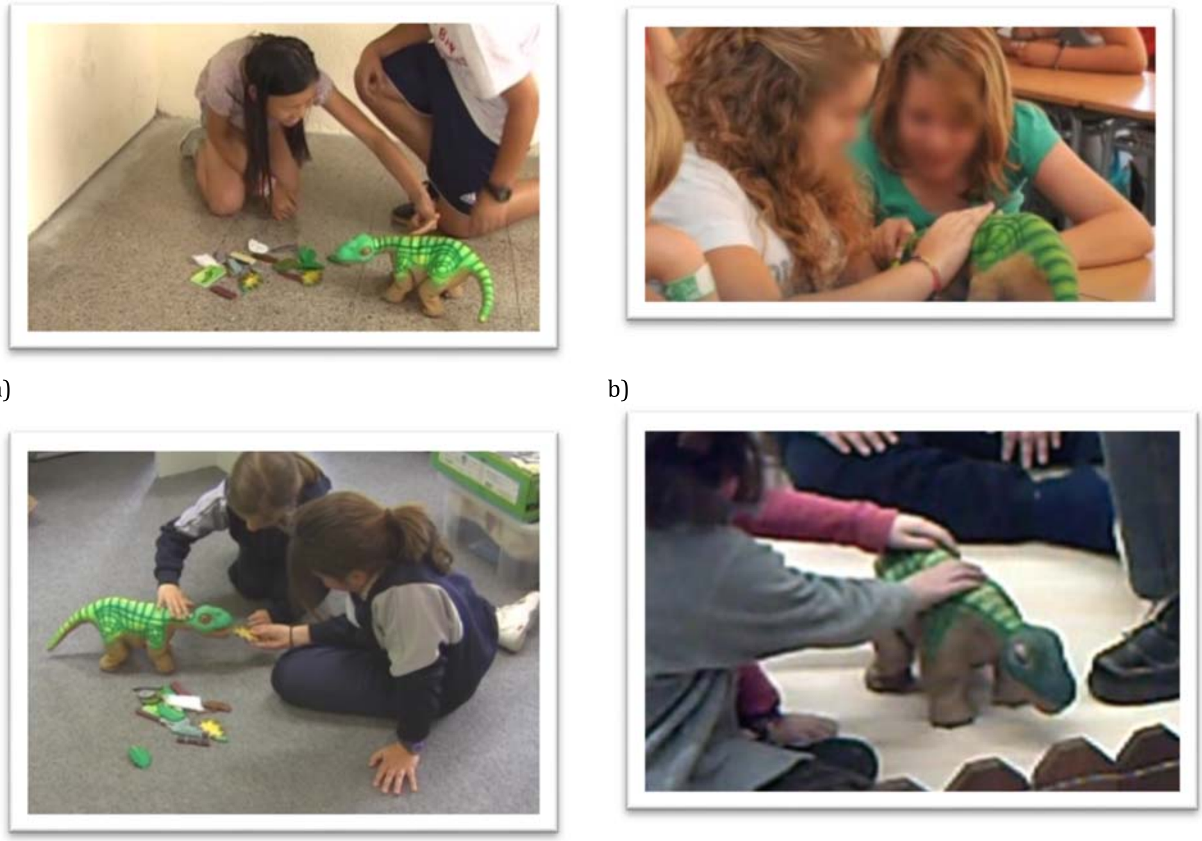


a)

b)

c)

Figure 4-18 Giving Affection > Substantial contact
a) and b) In lap, c) Carry



a) b) c) d)

Figure 4-19 Giving Affection > Contact Other> Pet

a)

b)

c)

d)

Figure 4-20 Giving Affection > Contact Other > Pet> Scratch

a)

a) bis

b)

b) bis

c)

Figure 4-21 Giving Affection > Contact Other> Kiss

a)

Figure 4-22 Giving Affection > Contact Other > Groom

a)

b)

c)

d)

Figure 4-23 Giving Affection > Contact Other >Touch
a) Poke Head, b) Touch tail, c) Pinch back skin, d) Scratch

a)

b)

c)

d)

Figure 4-24 Attempts at reciprocity
a) Present b) Offer, c) and d) Social Bids

a)

b)

Figure 4-25 Agonistic > Aggression
a) Hold by the tail; b) Hit on the head

4.5.4. Psychological State

Even though the ethogram is focused on the *interactive surface* or *interactional practice* of children's behavior, according to the model of bond forming presented in Chapter 3, children psychological state during interaction is the key factor in engagement dynamics and eventual bonding. Positive emotions towards Pleo like curiosity, enjoyment, and interest act as a reinforcement of the activity towards Pleo while negative states like boredom, apprehension or frustration act as negative reinforcement and reduce the willingness to keep interacting and consequently restrict the chance of developing a tighter bond.

One very interesting reference to measure child emotions in a comparison study between two kind of programs to provide emotional support and diversion to hospitalized children: Child-life therapy programs and pet-therapy was proposed by Kaminski (Kaminski, Pellino, & Wish, 2002). One of the outcome variables measured to assess the effectiveness of pet-therapy was displayed affect that was assessed from the videotaped data, according to the coding scheme summarized in Table 4-14.

Table 4-14 Coding scheme for videotape analysis of children displayed affect
(Kaminski et al., 2002)

Categories	Behavior
Positive affect	Expression of positive, warm, kind, loving attitude. Displayed by smiles, laughter, positive excitement, sharing playfulness, and pride in accomplishments.
Negative affect	Expression of frustration, anger, negativity, depressed affect, or cold/rejecting attitude. May be manifested by crying, whining, scowling, frustration, anger, lack of interest or pleasure in social stimuli, expressed helplessness or hopelessness, absence of vocal expressions or facial animation, vacant or unfocused gaze, and little or slow movement.
Anxious-fearful affect	Expression of fear, apprehension, hesitancy, motor tension, nervous laughter, or clinging behavior. May be manifested by child appearing wary, tense, fearful, or apprehensive. Hesitancy, rocking, pulling on ear or hair, motor tension, thumb sucking, baby talk, stuttering, nervous laughter, or persistent questioning or self-doubt may be evidence
Neutral affect	No evidence of above affects. Neutral expression.
Touch-physical contact	Gentle, warm, sensitive touching, hugs, kisses by child to dog or staff or from staff to child.
Persistence-on task	Maintains goal-directed behavior. Eye contact with project–dog–staff. Shows interest in project–dog. Speaking to, touching, smiling at, playing with, or otherwise responding to task–staff–dog. Actively participating in task.

Note: All affect items include using tone of voice, facial, and other body language cue

In this section we organize and describe the categories and behaviors that we consider the key psychological states involved in child-Pleo interaction and in the dynamics of bonding, according to the antecedents, the theoretical framework and our own empirical data.

This category of Psychological States has not been included in the coding scheme.

Apprehension

The child exhibits a startle response, wariness, withdrawal or other intentional movement away from the artifact (e.g. Pleo yells and child backs away quickly). Provided the harmless appearance of the robot as a machine, apprehension behaviors seem to imply perceiving the robot as a threaten because of its animal-like behavior. The origin of this negative attitude may be founded on analogies with other animals, with other representations of animated objects –from literature, video games, and movies- or on the unpredictability of an animated estrange entity. Apprehension should decrease to emerge successful interaction and long-term relationship. Apprehension can be influenced by experience –direct or vicarious- or through persuasion, and it is not likely to appear lately or to increase once it had diminished because of the interaction of Pleo usually reinforce the perception of robot's innocuity and niceness.

Enjoyment

Some amount of amusement should appear to generate engagement, emotional attachment and to reinforce the willingness to keep interacting. Normative children (differently from children with pathological behaviors as stereotypes or compulsive behaviors) orient naturally to entities or situations that provide some kind of pleasant experience. We consider a pleasant experience a necessary condition for the emergence of companionship. Enjoyment seems to be the key concept to consider an interaction as successful (*successful interaction* is defined by the amount of amusement and delight showed and the willingness to continue or resume interaction).

Frustration

Frustration is a negative emotion linked to the inability to obtain an expected/desired outcome. This feeling of failure could result alternatively in keeping on trying to achieve one's goal –as in the flow of engaging challenging games- or in giving it up, depending on situational (e.g. how many times the goal is frustrated, the perceived external support, previous successful experience) and individual variables (e.g. personality traits related to frustration tolerance). Most importantly for our model, frustration may reinforce the interaction or –most commonly-inhibit it.

Boredom

Is the lack of interest in a situation that does not provide exciting, valuable or interesting outcomes in terms of individual's subjective experience. Boredom appears as well when not valuable or interesting outcomes are anticipated.

Where we cannot attribute to children any of the previous psychological states but the child shows attention the *Neutral* category is a container unit. Any case, observing normative children it is rare not to be able to identify either positive or negative moods or emotions for long time during a play situation.

Table 4-15 Psychological States

1. Apprehension		
1.1.Startle		A jerky reflexive movement. This may include a surprised facial expression, but the facial expression is not a basis for the startle. May be with or without words or vocalizations
1.2.Wariness		Intentional moving away (upper body or whole body) from Pleo with some level of apprehension.
1.3.Verbal		
2. Enjoyment		
2.1.Excitement		Facial expressions, expansive gestures with arms/body (e.g. jumps, raising both arms in victory), clap hands. Implies a high level of activation, exultation, enthusiasm, lively or triumphant joy that implies agitation and expansive behaviors.
2.1.1.	Laugh	Typical smile and sounds with the voice in amusement when you find something funny
2.1.2.	Gestures	Conventional gestures for showing joy or exaltation as victory sign with two fingers or applause. Expansive gestures as expression of exaltation and amusement or agitation **(Fig. 4-28)**
2.1.3.	Movements	Expansive movements that involve the whole body with (i.e. running around) or without displacement (i.e. jumping) expressing exultation or joy. **(Fig. 4-26; 4-27)**
2.1.4.	Vocalization/ Verbal	
2.2.Pleasant		
2.2.1.	Smile	Facial expression that involves an upturning of the corners of the mouth
2.2.2.	Broad Smile	Facial expression with mouth open or lips separated showing the teeth **(Fig. 4-26; 4-28)**
3. Frustration		Feeling of dissatisfaction, anger or annoyance, resulting from being unable to do something, unfulfilled needs or unresolved problems.
4. Boredom		The child orients and or looks other than at Pleo or Pleo gadgets or people interacting with Pleo for more than 3 seconds
5 Neutral		The child is somehow engaged in the interaction (e.g. looking at Pleo) and exhibit a neutral expression and behavior that cannot be labelled neither as positive nor negative

a)

b)

a)

b)

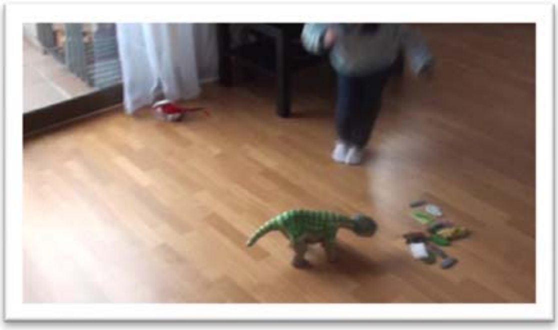
c)

d)

Figure 4-26 Enjoyment > Excitement;
a) Wide Smile; b) Jump a) to d) Gestures (clapping) and Movements (Running around Pleo)

a)

b)



c)

d)

Figure 4-27 Enjoyment > Excitement>Jump

a) b)

c) d)

Figure 4-28 Enjoyment > Excitement
a) and b) wide smile; c) Gestures (Clapping hands)

a) b)

Figure 4-29 Frustration
a) and b) banging (slamming) on the table (at Pleo falling asleep during active interaction)

4.6. Patterns of Dyadic Interaction

A pattern is a reiterative sequence of behavioral units in the same order. The behavioral patterns have an empirical anchorage, a particular unit that explains the temporal link of a whole sequence. In our system, the patterns of dyadic interaction are defined as *sequences of coordinated* or *contingent action* between children and Pleo. From our theoretical assumptions we hypothesize that successful sequences of contingent behavior have a central role not only at cognitive level –as a mean of interpreting and reinterpreting perceptions and categorizations of Pleo status and performance- but as well as a reinforcement of bond forming. These sequences imply the child bidding Pleo and the robot responding accordingly.

Our approach goes in line with Pitsch proposal to apply conversational analyses to systematic study of children interacting with Pleo (Pitsch & Koch, 2010). This perspective includes the context as a part of the object of study and regards interaction as a dialogue between the child and Pleo where any behavior unit draws its meaning from the flow of the interaction in a particular scenario, one action making another action contingently relevant composing a meaningful sequence in terms of functionality in the pretend play (i.e. feeding or playing).

We agree with Pitsch that

> While questionnaires/interviews and coding of videotaped HRI (of measures such a physical distance, contact or body position) are able to reveal a general attitude towards these systems, but they won't be able to take into account the *interactional practices* which participants use to explore the system, whether/how their behavior and their perception might change over time and which features of the robot's conduct they might treat as relevant for their categorizations. (Pitsch & Koch, 2010).

Dyadic patterns unfold following an internal structure: they are initiated by a child's bid –based or not in a particular antecedent Pleo's behavior- that is followed by a Pleo's contingent response. Differently from the children's behavior category *Attempts at Reciprocity*, in a *Dyadic Pattern* these attemps should be followed by a contingent response by Pleo. This *dialog* requires some previous experience to acquire enough "social competence" to coordinate the sequences of actions with Pleo successfully, with or without external help (i.e. peers' or adults' hints that act as facilitators).

According to our model of bonding dynamics, the identification of these sequences is especially relevant by two reasons. First, because they imply that the robot is regarded by the child as an animate social-situated entity that is able to engage with her in re-occurring interactional patterns (Pitsch & Koch, 2010). Secondly, because in our model, the experience of successful (i.e. meaningful) sequences of interaction is the most powerful reinforcement of engagement and bonding.

4.6.1. Categorization Criteria

Dyadic Patterns are classified into *Epimeletic/etepimeletic* sequences (i.e. feeding and taking care), *Play* and *Agonistic* behaviors. This categorization responds to a functional criteria and divides the patterns according to their meaning in a owner-pet space for interaction.

It is important to notice that Pleo's ability to respond contingently is restricted to four behavioral displays: opening the mouth and biting, snuggling notably when hugged and pressed to the bosom, slowing down the movements when been caressed and contorting when been treated roughly. Taking and releasing with the mouth is a meaningful response in feeding and play sequences (i.e. tug). Concurrent vocalization as *Chew* when *Mouthing* a piece of food, or *Purr* when hugged, help to make sense and emphasize the whole sequence but are very difficult to register from the observer position. Thus, we do not include vocalizations in the sequence analyses, though its unquestionable communicative value (see Section *4.4.1. Categorization criteria*).

It is important to point out that these behaviors may or may not occur contingently to children's specific bids (e.g. present/offer; stroke). Therefore, only sometimes Pleo's response meets children expectancies because contingent responses do not appear deterministically after every instance of children's initiating behaviors. This pattern of not deterministic contingency is a very specific situation, -probably not very different from owner-puppy interaction when trying to train new skills or obedient responses-. This situation is critical in our model because the lack of consistence in Pleo's behavior not only difficult children understanding of Pleo's behavior and *mind* but also can provoke frustration, boredome or disengagment (see a discussion on *Dyadic Patterns* in Section *4.7.2.2. Results*).

4.6.2. Inventory

Table 4-16 Sequences of Child-Pleo contingent behaviors

	Category	Description
1.	**EPIMELETIC/ ETEPIMELETIC**	Complementary behaviors of care and attention giving and attention getting and care soliciting and showing content
	1.1.Feed	**(CH) Offer- (PL) Open the mouth - (CH) Put in the Mouth - (PL) Take (chew)** Most frequently the feeding sequence is initiated by Pleo opening the mouth or the child presenting/offering an object putting it close to Pleo's mouth or mussel. The child move may be followed by Pleo orienting to and/or opening the mouth or withdrawing as *rejecting* (turns the head away from the piece of food or gadget or object presented). There could be many sequences of offering that eventually can end by the child putting the object into Pleo's mouth with or without helping/forcing (i.e. opening the mouth with the hands or separating the jaws pushing the object through them). The third step is Pleo's mouthing the object with their jaws completely and the child releasing it. The third step is Pleo keeping the object in the bite and uttering chewing sounds.
	1.2.Cuddle	**(CH) Press to bosom/In Lap- (PL) Snuggle** The child hold close to the body Pleo in an affectionate manner, hug tenderly and eventually rocking it, while Pleo flexes the legs allowing full contact with the body while slowing the movements and getting quiet and calm, snuggling pressing closely against, as for comfort or from affection and eventually purr in content
	1.3.Rock	**(CH) Press to bosom/In Lap- (PL) Snuggle (and eventually) fall asleep** Similar to Cuddle but rocking Pleo to sleep. Pleo rests quiet and closes the eyes and eventually purrs or snorts.
	1.4.Caress	**(CH) Stroke- (PL) Calm down** Pleo pushes into child stroke or responds to soft chin-scratch jut out its chin and close the eyes (and eventually purrs) as in content, appeasing the movements and lowing the vocalizations.
2.	**PLAY**	**(CH) Put in the Mouth-(PL) Take-(CH) Pull- (PL) Strive to keep** Child and Pleo engage in a content tugging, struggling exerting opposed forces to pull and keep something that Pleo mouths vigorously.
3.	**AGONISTIC**	**(CH) Hold by the tail / restrain forcefully- (PL) Contort** When Pleo is suspended downwards by the tail and shaken or restrained forcefully for instant in a tight hug, it struggles agitatedly and vigorously or contort as in panic or rage, for instance while is forcefully restrained.

a)

b)

c)

d)

e)

Figure 4-30 Epimeletic/ Etepimeletic > Feed

a) b)

Figure 4-31 Agonistic > Hold by the tail/Contort

4.7. The Coding Scheme

4.7.1. First Proposal

An *ad hoc* coding scheme was derived from the children's, Pleo's and dyad's ethograms, selecting the most relevant behaviors according to our research questions, theoretical assumptions and the observational setting. Bakeman and Gottman (cited in Bakeman & Quera, 2011,13) affirmed that using someone else's coding scheme was like wearing someone else's underwear, highlighting that codes and underlying theories need to connect.

A coding scheme is the primary instrument of observational methods, consisting in a list of names or categories –or less often, ratings- that observers then assign to the observed behavior. The coding scheme is an instrument like a thermometer or a balance, the difference is that a coding scheme is primarily nonphysical but conceptual. Bringing the phenomena of interest into focus for systematic observation, the coding scheme limits the attention of the observers and state what is important to be observed and what aspects we should focus on, thus making theoretical commitments (Bakeman & Quera, 2011,24).

Inspired in the antecedents of coding schemes developed to measure child-robot interaction (see Section *4.5.1.Antecedents*) and on our previous observations of child-Pleo play we present here the rational and structure of the coding scheme built up and applied to a behavioral data-set for discussion and refinement in an iterative process.

The coding scheme is divided in three sets according to the actors observed: Pleo's behavior (11 codes), children's behavior (26 codes) and dyads' patterns (6 codes). In Tables 4-17 to 4-19 the behaviors selected from the ethograms are listed with the code assigned, the type of behavior (point event or state event) and indications and rules of coding.

Pleo's behaviors

From Pleo's repertoire we selected 11 behaviors that are not simple movements (micro-behaviors) but movements that convey some communicative content in the flow of interaction. Even though micro behaviors (i.e. blink, open the mouth) have the advantage to be well identifiable, low level and action/movement categories (Dautehnhan and Weary 2002) we would rather describe behavior in terms of the social context and its effect on interaction (i.e. consequence).

From the category *Attention Seeking*, *Agitation* was not selected provided is a Pleo by default state not clearly contingent to particular events or actions, that appears generally when Pleo is awake and it is not interacted physically. Following the rational above, single simple movements (e.g. raise one leg; move the tail side to side) that are followed by a clear children response (e.g. *Look*!) are registered as *Funny movements* because they are communicative, while the rest of movements are not included.

Orient/Gaze was discarded as well because to be coded require a close-up observation that was not supported by the current set up of the observational data base.

From the category *Feeding Related, Open mouth* is not selected as a single behavior but is scored as an element in the *Dyad's Patterns Feed*. Pleo opens the mouth very frequently sometime to utter vocalizations and in this case are not coded. *Chew* was not selected because this contextual distinctive sound -that happens eventually when Pleo is mouthing a piece of *food*- was not audible in the set up and we are not sure that was so for children, losing in this case any potential meaning or interest as communicative behavior.

From the category *Affection related* none individual code was derived, but the behaviors are taken into account as a significant element in epimeletic episodes in *Dyadic Patterns* (Table 4-17).

From the category *Gestures*, the behavioral units *Nod, Shake Head* and *Instant Freeze*, were not included because they were not observable in the current set-up. Finally *Turned off* is not observable provided according to the trials' procedure the children encountered Pleo activated and it was not turned off during the play neither by children –it is not an intuitive manipulation- nor by the session facilitator.

All the behaviors belonging to the Pleo's ethogram sub-category *Activated Performance* were not considered because, by definition, these behaviors do not appear in the observational setting of unstructured play with naïve participants.

All the behaviors are defined as point events (i.e. without considering duration) except the two possible states of Pleo, *on* or *off* (i.e. *Sleep)*. The time Pleo's reminds slept or inactive is relevant and is not discounted from the session's total time because interaction does not stop. Conversely, in session 6, when Pleo had to be removed from the play zone, the time of its absence was discounted to estimate time related measures as rates.

The Pleo's codes set is neither exclusive (e.g. movements and vocalizations can co-occur) nor exhaustive (i.e. several Pleo's actions and movements of Pleo's ethogram are not included in the scheme).

Table 4-17 Pleo's behavior included in the coding scheme

Categories and behavior units		Code	Type	Rules of coding
1. SPONTANEUS ACTIVITY				
1.1. Not social				
1.1.1. **Locomotion**				
1.1.1.1.Walk Ahead	**1**	WalkAhead	Point	
1.1.1.2.Walk Backwards	**2**	WalkBack	Point	
1.2. Social				
1.2.1 **Attention seeking**				
1.2.1.1. Agitation				
1.2.1.2. Funny movements	**3**	FunMov	Point	
1.2.1.3. Orient/Gaze				
1.2.1.4. Calls	**4**	CallFriend	Point	
	5	CallDist	Point	
1.2.1.5 Agonistic	**6**	ThreatDisp	Point	
1.2.2. **Feeding-related**				
1.2.2.1. Open mouth				
1.2.2.2. Take/Mouth	**7**	Mouth	Point	
1.2.2.3. Chew				
1.2.2.4. Belch				
1.2.2.5. Release	**8**	Relea	Point	
1.2.3. **Affection-related**				
1.2.3.1. Snuggle				
1.2.3.2. Calm down				
1.2.3.3. Purr				
1.2.3.4. Nap				
1.2.4. **Play**				
1.2.4.1.Invitation to Play	**9**	Invitation	Point	
1.2.4.2.Tug	**10**	Tug	Point	
1.2.5. **Gestures**				
1.2.5.1.Nod				
1.2.5.2.Shake Head				
1.2.5.3.Squint				
1.2.5.4.Instant Freeze				
1.2.5.5.Bow				
1.2.5.6.Cringe				
2. INACTIVITY				
2.1. Asleep/Collapsed	**11**	Sleep	State	
2.2. Turned off				
3. ACTIVATED PERFORMANCE				
3.1. Tricks				
3.1.1. **Balance**				
3.1.1. **Sit down**				
3.1.1. **Burst of laughing**				
3.1.1. **Faint**				
3.2.Learned behavior				
3.2.1. **Bow**				
3.2.1. **Come**				
3.2.1. **Sing**				
3.2.1. **Count**				
3.4. Turned On-Off				
3.3.1. **On**				
3.3.2. **Off**				

Children's behaviors

All behaviors described in the children's behaviors ethogram (Table 4-12) were included in the coding scheme sub-set of 26 codes. In Table 4-17 are indications and rules for coding, especially to identify interpretative behaviors (e.g. *Feed*, *Mistreat*) and to differentiate between similar actions (e.g. *Offer/Present*) and especially to distinguish between children's social and non-social behaviors towards Pleo

To easily identify the units as belonging to one of the three key categories of *Handle as an Artifact*, simple social behaviors (encompassing *Giving Affection* and *Agonistic*) and *Attempts at reciprocity* the codes incorporate the prefix *Art-*, *Soc-* and *Att-* respectively. The codes labelling are selected following Bakeman and Quera indications (2011).

All codes are defined as point events except for the 4 behaviors included in the sub category *Substantial contact* (*SocBos, SocLap, SocHug and SocCarry*) that are considered state codes and can co-occur with the other point event codes (e.g. petting Pleo while keeping it on the lap).

At the highest level the children's codes subset is designed to be exclusive and exhaustive to assess the time children spent engaged in interaction. Thus, the overarching categories of *Engagement* and *Disengagement* are exhaustive and mutually exclusive.

At lower levels the coding scheme is not exhaustive in terms of covering all children's activity during the session. The coding addresses only the physical interaction towards the robot not including verbal behaviors that are treated separately from transcripts (Appendix B). Behaviors of children exploring Pleo's material, talking to each other about Pleo or asking the conductor about the activity are not included either as individual actions but the time spent in this activity do not interrupt *Engagement* state. In the discussion we address the convenience of including these behaviors in the coding scheme.

Finally, children psychological states, though central in our model of bonding as accounting for their subjective experience, are not included in the observational coding scheme. In the discussion we address the convenience and issues of including the emotional expression in further refinements.

Table 4-18 Childrens's behaviors included in the coding scheme

Categories and behavior units		Code	Type	Rules of coding
1. ENGAGEMENT				
1.4. Handle as an artifact				
1.1.1. **Exploration**	1	ArtExp	Point	A difference from *look at* behavior, implies some posture (e.g. leaning forward), movement (e.g. approach) orientation or adaptation to better observe. Unlike ArtMan, there is not physical contact with the robot.
1.1.2. **Manipulation**	2	ArtMan	Point	
1.1.3. **Handling**				Without the sense of inquisitiveness
1.1.3.1. Mouth				Manipulations that involve Pleo's capability to open the mouth and take
. 1.1.3.1.1. Put in the mouth	3	ArtMouth	Point	Differently from AttFeed *Put into the mouth* is not preceded by *Offer* (AttOffer) because is not an attempt to stablish a sequence but just an action on the robot.
1.1.3.1.2. Take from the mouth	4	ArtTake	Point	
1.1.3.2. Other	5	ArtOther	Point	
1.1.3.3. Displace	6	ArtDisp	Point	
1.1.4. **Rough Manipulation**	7	ArtRough	Point	
1.5. Social interaction				
1.2.1. **Giving Affection**				
1.2.1.1. Substantial Contact				
1.2.1.1.1. Press to bosom	8	SocBos	State	
1.2.1.1.2. In Lap	9	SocLap	State	
1.2.1.1.3. Hug	10	SocHug	State	
1.2.1.1.4. Carry	11	SocCarry	State	
1.2.1.2. Contact Other				
1.2.1.2.1 Pet	12	SocPet	Point	To avoid underestimation a new occurrence has to be counted every 2 seconds and/or whenever changing the way of performing the behavior (i.e. scratch, rubber) and/or changing the hand with which the child pets the robot or the part of Pleo's body caressed.

1.2.1.2.2. Kiss	13	SocKiss	Point	
1.2.1.2.3. Groom	14	SocGroom	Point	
1.2.1.2.4. Touch	15	SocTouch	Point	
1.2.2. **Attempts at reciprocity**				
1.2.2.1. Attention seeking	16	AttAtt	Point	Action [--->Get attention/Awake] With or without physical contact attempt at Pleo's attention getting or orient to the child or to awake when Pleo is asleep. With physical contact the action (e.g. hit, shake) should be gentle if not register as SocHit or SocMis. Instances without physical contact are snap fingers, wave, whistle, clap hands, clasp table/floor.
1.2.2.2. Present	17	AttPres	Point	
1.2.2.3. Offer	18	AttOffer	Point	
1.2.2.4. Feed	19	AttFeed	Point	(Offer--->)Action [---->Take] Differently from *Put in the Mouth*, *Feed* is always preceded by *Offer* (AttOffer)
1.2.2.5. Cuddle	20	AttCudd	Point	
1.2.2.6. Social Bids	21	AttBids	Point	Conveys communication as requesting or soliciting a response OTHER THAN catching Pleo's attention (AttAtt)
1.2.3. **Agonistic**				
1.2.3.1. Aggression				
1.2.3.1. 1. Hit	22	SocHit	Point	Implies coercive, punitive intention, not only attention getting (AttAtt)
1.2.3.1. 2. Mistreat	23	SocMist	Point	Force feeding is considered *Rough Manipulation* (ArtRough) except when is preceded by *Offer* (AttOffer)
1.2.3.2. Defense	24	SocDef	Point	
1.6. Attentiveness				
2. **DISENGAGEMENT**				
2.1. Refuse Interaction	25	Refuse		
2.2. No Interaction	26	NoInte		

Dyadic patterns

Dyadic patterns are complex in nature because are sequences of behaviors involving Pleo and at least one of the children present. The coding of these patterns is done once the individual behaviors both from children and Pleo has been coded. Then critical behaviors (e.g. Pleo's mouthing a piece of *food*) -that are the empirical anchorage of the patterns- are identified and its antecedents and consequences reviewed to eventually fit a pattern. Thus, some behaviors are coded twice, as an instance of an individual code and as an element in a pattern (e.g. *Mouth*).

All six patterns from the three categories (i.e. *Epimeletic/etepimeletic*, *Play* and *Agonistic*) are included in the coding scheme (Table 4-17). The patterns allow some variability that is summarize in the *Sequence* column.

Table 4-19 Dyadic patterns included in the coding scheme

Categories and patterns		Code	Sequence
1. EPIMELETIC/ ETEPIMELETIC			
1.1. Feed	1	Feed	(CH) Offer --> (PL) Open the mouth --> (CH) Put in the Mouth --> (PL) Take --> [Chew] --> (CH) Take/(PL)Release
1.2. Cuddle	2	Cuddle	(CH) Press to bosom/In Lap --> (PL) Snuggle
1.2. Rock	3	Rock	(CH) Press to bosom/In Lap --> (PL) Snuggle --> (PL) Fall asleep and eventually Snort
1.4.Caress	4	Caress	(CH) Stroke --> (PL) Calm down
2. PLAY	5	Tug	(CH) Put in the Mouth --> (PL) Take --> (CH) Pull --> (PL) Strive to keep
3. AGONISTIC	6	Contest	(CH) Hold by the tail / restrain forcefully --> (PL) Contort [(PL) Call Distress]

Note: in square brackets behaviors that may occur but that are not essential
Note: behaviors separated by a slash are alternative

4.7.2. Test

To refine and adjust the behavioral system, the coding scheme was applied to analyze the interactive behavior of 12 children interacting with Pleo in pairs in a short play session at their school. These set of observations were segregated from a data-set of 18 trials (36 participants aged between 6 and 12) gathered in two different primary schools in Barcelona during 2011. Another subset of 12 trials was analyzed in a former study on children interaction with Pleo with an emphasis on the social and agency attributions. Results on social presence are available in (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012).

The observational data set analyzed in the present dissertation had not been processed neither included in any former study.

4.7.2.1. Method

The study consisted in a unique session of 6th degree children free play with Pleo in pairs in a controlled environment at their school. We chose to observe children playing in pairs to enhance children verbal production talking to each other to complement and contextualize the behavioral data and to obtain more knowledge on their reasoning and judgements on Pleo and their subjective experience during interaction (see Appendix B for the transcript of verbal behavior). Making their actions accountable for the co-participant and displaying their interpretations of the co-participant's actions, children spontaneously *externalize* their reasoning, judgements and intent. Using this setting children's *practical reasoning* would be more available for analysis and reconstruction (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012; Pitsch & Koch, 2010).

Participants

12 typically developing children -6 girls and 6 boys- aged between 11 and 12 took part in the sessions grouped in pairs. The participants were selected and paired up by their teacher from the scholars of 6th grade and took part in the session with Pleo as a complementary activity while the rest of the group attended a special science's lesson on robotics given by a member of the research team. In Fig. 4-32 we can see the snapshots of the six pairs of children during the sessions.

a) Session OO Child 1(girl) and Child 2

b) Session PP, Child 3 (girl) and Child 4

c) Session QQ, Child 5 (girl) Child 6

d) Session RR, Child 7 (in red) and Child 8

e) Session SS, Child 9 (girl) and Child 10

f) Session TT, Child 11 (in white) and Child 12

Figure 4-32 Pairs of participants during the play sessions with Pleo

Setup and Procedure

The trials were designed as play sessions to observe the dyad's spontaneous and unconstrained interaction with the robot. The play sessions were carried out in a specially arranged area in a separated class-room.

Each couple was brought from the regular classroom to the test room in the moment they had to take part, with the only instruction to play with Pleo for a while. In the play area they found the Pleo on the floor activated (i.e. turned on) and several pieces of Pleo's toys and food scattered in the floor around it (Fig. 4-33 and 4-34). The play material provided were food and toys purchased to the company, and concretely six leaves of four different kinds, a rock salt, the so called *Tug of War* -a round piece like an stone with a rough string, a sugar cane, a chunk of ice, six different *learning stones* and the ID card, (Fig. 4-33).

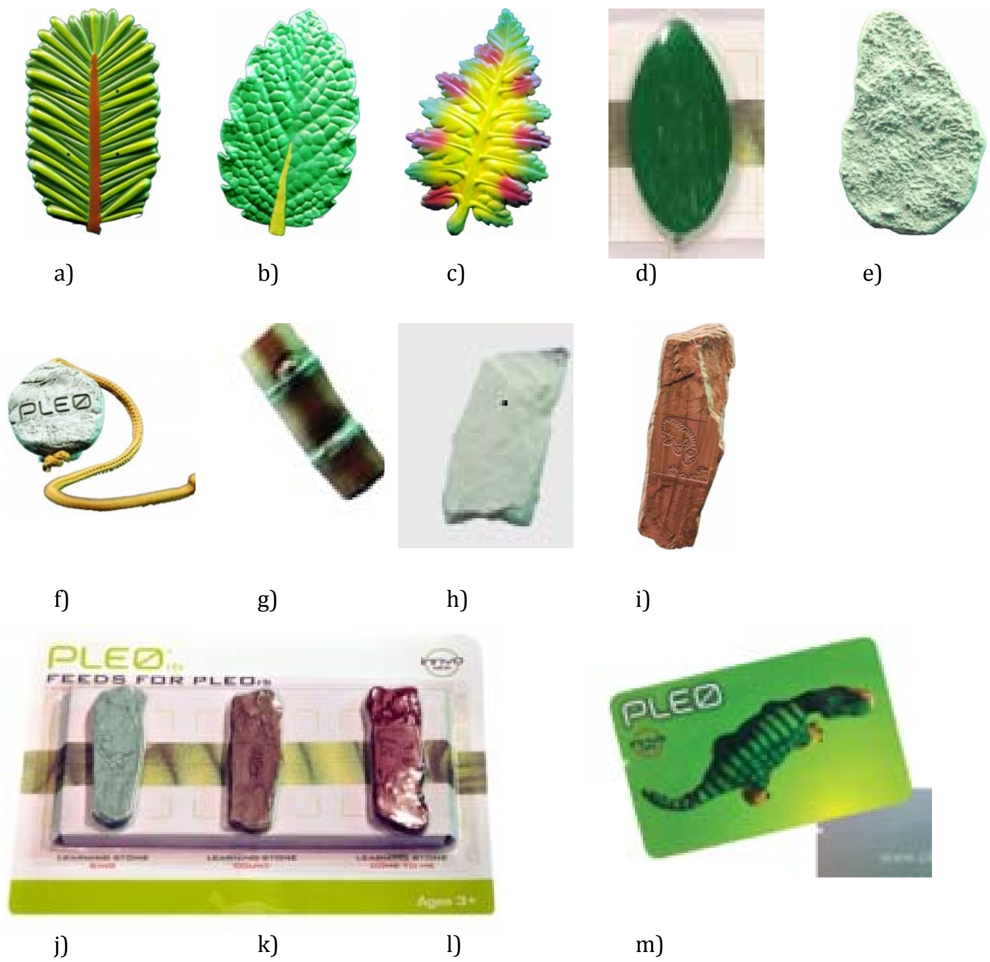
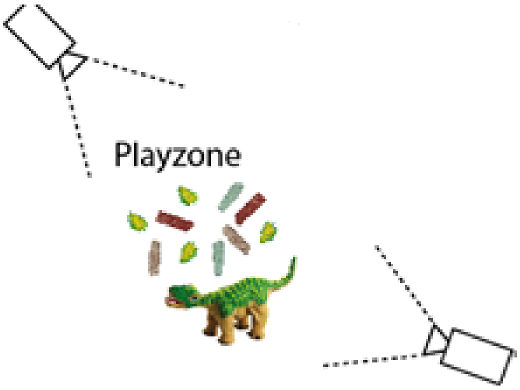


Figure 4-33 Pleo's food and toys

a) Conifer Leaf; b) Mint Leaf, c) Training leaf , d) Cicad Leaf, e) Rock Salt, f) Tug of War, g) Sugar Cane, h) Ice, i) to m) Learning stones *Bow*, *Count*, *Come to Me, Sing*, n) Identity Card

The conductor stepped backwards and stayed in the same room while children were playing freely for 8 minutes. Neither the conductor nor the other researcher initiated any interaction with the children. When addressed by the children, the conductor responded in a deliberate neutral way. The conductor took the initiative when Pleo's eventually entered the sleep mode and had to be *awakened* (i.e. pressing the *on* button in Pleo's belly).



a)

b)

Figure 4-34 The play scenario and the observation setting
a) Diagram of Pleo, its material and the 2 cameras; b) Children entering the play area

The conductor and the observer - the author- stayed outside the play area and observed taking notes of any relevant contextual information. A third researcher attended when required by the conductor to give technical support (e.g. in case of Pleo's malfunctioning). The play sessions were video recorded with two cameras for further analyses (Fig. 4-34). When the play time was over, the conductor entered the play area, told the children that the play session had finished, turned off the robot and instructed them to answer the questionnaire individually with the help of one of the two researchers.

The whole session took about 15 minutes for every couple including the posttest debriefing and the questionnaires completion.

Questionnaire

A questionnaire was administered after the play session to investigate children's perceptions on Pleo. The questionnaire was in three parts: a five items Likert-type scale with 5 points to measure the sense of presence featuring statements inspired on the social presence questionnaire developed by Bailenson (Bailenson, Blascovich, Beall, & Loomis, 2001; Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012) (Table 4-20).

Table 4-20 Social presence items

1. When playing with the robot, I felt like playing with a real person
2. I sometimes felt like the robot was actually looking at me
3. I can imagine the robot as a living creature
4. I often realized the robot is not a real living creature
5. Sometimes it seemed as if the robot had real feelings

Another subset of questions explored the children's attributions to Pleo through selecting adjectives from an *ad hoc* elaborated list of 20 words that could be used to describe the robot. Half of these words were referred to a social entity: kind, unkind, polite, rude, naughty, clever, stupid, angry, impatient and patient. The other ten words were more object oriented describing properties of toys or devices: useful, useless, easy, simple, complex, breakable, solid, new, old fashioned and artificial. Both subsets include positive (e.g. clever; useful) and negative features (e.g. stupid, old-fashioned).

The third set of items was formed by 6 YES/NO questions based on the questionnaire designed specifically for children up to 15 years old by Weiss (Weiss, Wurhofer, & Tscheligi, 2009) to investigate emotional attachment with the robotic pet dog AIBO after interaction (Table 4-21). The questions addressed cognition (questions 1 and 2), emotional attachment (questions 3 and 4) and social reciprocity (questions 5 and 6) (for more details about the questionnaire see Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012).

Table 4-21 Emotional attachment items

1.	Do you think Pleo can see you?
2.	Do you tink Pleo can undestand you?
3.	Do you tink Pleo is happy if you strok him?
4.	Do you tink Pleo can be sad (e.g. if hi/she is alone)?
5.	Could Pleo be your playfellow?
6.	Would you feel better, if Pleo is with yu when you are at home alone?

We added three more open questions asking the children to give Pleo a name, and their guesses on its gender and age.

4.7.2.2. Results

Data collected

The planned session duration was 15-20 minutes, including 8 minutes of play with Pleo and the completion of the questionnaire. The current play sessions lasted between 496s and 849s with a total of 3.216 seconds of play observed and video recorded throughout the 6 trials. During the last observation Pleo's neck was blocked and the robot had to be removed by the third researcher to be fixed. The total time that Pleo was absent (163s) was discounted to calculate the behavior rates.

All children completed the sessions and filled the questionnaires.

Verbal behavior was recorded and verbatim transcribed (see Appendix B).

The behavior analyses was done with the Noldus software Observer XT 10.5 and the IBM SPSS Statistical 12.

Pleo's behavioral data

All Pleo's observed behaviors were event (not timed) data -except Pleo's state *Sleep*- and are treated as individual codes.

As can be seen in Table 4-22, up to 120 Pleo's behaviors were coded throughout the six sessions grouped into the five overarching categories *Attention seeking, Feeding, Play* and *Inactivity*. None *Locomotion* behavior was observed. Table 4-22 reports the frequency of each behavior in each session, and the duration for the state event *Sleep*. The most frequent behaviors were *Amiable Call* (37 observations) followed by *Mouth* (30 observations). By categories, *Attention Seeking* was the most observed with 50 observations (42% of the total behaviors observed).

Table 4-23 presents the following summary statistics related both to single codes and to categories: frequency (number of times a behavior occurred), minimum (the least quantity of occurrences observed in one session), maximum (the highest amount of occurrences observed in one session or in one subject), mean (frequency divided by number of sessions), standard deviation, relative frequency (a code's frequency divided by the sum of frequencies for the codes specified), rate (frequency divided by the duration of the session, in minutes), and duration (time spent in a behavior).

Table 4-22 Frequency and duration of Pleo's observed behaviors

		Behavior categories															
		Attention Seeking					**Feeding**			**Play**			**Inactivity**				
Sess	**Dur**	**Fun mov**	**Call Friend**	**Call Dist**	**Threat Disp**	**TOT ATT**	**Mouth**	**Relea**	**TOT FEED**	**Invit**	**Tug**	**TOT PLAY**	**Sleep (F)**	**Sleep (D)**	**TOT INAC (%)**	**TOT**
OO	512	0	0	0	1	**1**	7	5	**12**	0	0	**0**	2	123	**123 (24.02)**	**15**
PP	498	0	7	0	2	**9**	2	2	**4**	1	0	**1**	2	120	**120 (24.10)**	**16**
QQ	496	1	7	0	1	**9**	12	4	**16**	0	4	**4**	3	107	**107 (21.57)**	**32**
RR	510	0	11	0	1	**12**	2	1	**3**	2	0	**2**	3	136	**136 (26.67)**	**20**
SS	514	3	2	0	0	**5**	1	0	**1**	1	0	**1**	4	257	**257 (50.00)**	**11**
TT	686 [849]	1	10	2	1	**14**	6	4	**10**	0	0	**0**	2	77	**77 (11.22)**	**26**
	3,216	**5**	**37**	**2**	**6**	**50**	**30**	**16**	**46**	**4**	**4**	**8**	**16**	**820**	**820 (25.72)**	**120**

Note: In square brackets the total time recorded, from which the time Pleo was absent is discounted

Table 4-23 Summary of Pleo's behaviors

Behaviors		F	Min	Max	Mean	SD	Rel. Fre	Rate	Dur	Prob
Locomotion		**0**								
Attention Seeking		**50**	**1**	**14**	**8,33**	**4.72**	**0.42**	**0.93**		
1	Funmov	5	0	3	0.83	1.17	0.04	0.09		
2	CallFriend	37	0	11	6.17	4.36	0.31	0.69		
3	CallDist	2	0	2	0.33	0.82	0.02	0.03		
4	ThreatDisp	6	0	2	1.00	0.63	0.05	0.11		
Feeding		**46**	**1**	**16**	**7.67**	**5.79**	**0.38**	**0.86**		
5	Mouth	30	1	12	5.00	4.03	0.25	0.56		
9	Release	16	0	5	2.67	1.97	0.13	0.29		
Play		**8**	**0**	**4**	**1.33**	**1.51**	**0.03**	**0.07**		
6	Invit	4	0	2	0.67	0.82	0.03	0.07		
7	Tug	4	0	4	0.67	1.63	0.07	0.15		
Inactivity		**16**	**2**	**4**	**2.67**	**0.81**	**0.13**	**0.30**	**820**	**0.25**
8	Sleep	16	2	4	2.67	0.81	0.13	0.30	820	0.25
Total Activity		**120**	**11**	**32**	**20**		**1**	**2.24**		

Note: Rate is frequency per minute

Children's Behavioral Data

Up to 614 behaviors were coded throughout the sessions, with a total duration of 3216 seconds.

Disengagement was not observed, so *Engagement* duration is the observed time, and is not included in the analyses.

Children's interactive behaviors with Pleo were coded with the four overarching categories *Handle as an artifact*, *Giving Affection*, *Attempts at Reciprocity* and *Agonistic*, with a total of 24 behavior units as described in Table 4-13.

Table 4-24 reports all the occurrences observed and Table 4-25 reports the total, mean, minimum, maximum, standard deviation and relative frequencies of observed behaviors for every child and for every dyad (pair of children in a session). The *Appendix A. Plots of triadic interaction* collects the time series plots of the triadic interaction throughout the 6 sessions.

Analyzing the results by overarching categories, almost the half of children's observed behaviors belong to *Attempts at Reciprocity* (283 observations, 46%), followed by *Handle as an artifact* (238 observations, 39%), *Giving affection* (66 observations, 11%) and *Agonistic* (27 observations, 4%).

The behaviors from *Giving Affection* category *In lap*, *Hug* and *Carry* were not observed while *Press to Bosom* was only registered once. Hence only 1 occurrence of substantial contact with the robot was observed throghout the 6 trials.

Analyzing the results by units, the two more frequent behaviors belong to the category *Attempts at Reciprocity*: *Offer* (151 observations, 24.6%) and *Present* (72 observations, 11.7%), followed in a close group by *Manipulation* (52 observations, 8.5%), *Other Manipulation* (49 observations, 8%), *Petting* (47 observations, 7.6%) and *Put in the Mouth* (42 observations, 6.8%). It is remarkable that only one out of the six more frequent behaviors –*Petting*- belongs to the category of *Giving Affection*.

In terms of the *socialness* of the interaction, the 61.2% (376 observations) of children behaviors towards Pleo belong to social categories including both affiliative behaviors (*Giving affection* and *Attempts at Reciprocity)* and non-affiliative behavior (*Agonistic*). Nonsocial behaviors (*Handle as an artifact*) account for the other 39% (238 observations) of children's activity.

Every couple exhibited at least one instance involving mistreat towards Pleo. 22 aggressive behaviors towards Pleo as a pet (social behaviors *Hit* or *Mistreat*) were observed and 30 of rough handling, addressed towards Pleo as a device. In this last case of rough manipulation, 26 instances out from 30 were observed in one couple (1=18 and 2=8) belonging to a unique episode of violence that results in Pleo damaged and the session stopped for several minutes. On the other hand, 557 out of 614 behaviors towards Pleo (91%) were nice or neutral.

Table 4-24 Frequency of children's and dyads' observed behaviors towards Pleo

				Behavioral Categories: Handle as an artifact								Giving Affection						Attempts at reciprocity						Agonistic				
Obs	Dur	S	Gen	Art Exp	Art Man	Art Mouth	Art Take	Art Other	Art Disp	Art Rough	TOT ART	Soc Bos	Soc Pet	Soc Kiss	Soc Groom	Soc Touch	TOT SOC	Att Att	Att Pres	Att Offer	Att Feed	Att Bids	TOT ATT	Soc Hit	Soc Mist	Soc Def	TOT AGO	TOT
OO	512	1	Girl	0	3	0	0	0	2	0	**5**	0	11	0	0	3	**14**	1	5	8	1	6	**21**	0	1	2	**3**	**43**
		2	Boy	3	5	11	2	3	0	0	**24**	0	0	0	0	1	**1**	6	7	2	0	3	**18**	4	1	0	**5**	**48**
			Dyad	3	8	11	2	3	2	0	**29**	0	11	0	0	4	**15**	7	12	10	1	9	**39**	4	2	2	**8**	**91**
PP	498	3	Girl	4	0	0	0	5	0	0	**9**	0	1	0	0	0	**1**	0	0	2	0	0	**2**	0	0	2	**2**	**14**
		4	Boy	6	2	1	0	0	1	0	**10**	0	13	0	0	1	**14**	3	9	14	1	8	**35**	0	0	0	**0**	**59**
			Dyad	1C	2	1	0	5	1	0	**19**	0	14	0	0	1	**15**	3	9	16	1	8	**37**	0	0	2	**2**	**73**
QQ	496	5	Girl	1	7	9	5	2	2	0	**26**	0	3	0	1	6	**10**	2	8	25	4	0	**39**	5	3	0	**8**	**83**
		6	Boy	0	5	5	1	4	2	3	**20**	0	0	0	0	0	**0**	0	2	10	3	0	**15**	0	4	0	**4**	**39**
			Dyad	1	12	14	6	6	4	3	**46**	0	3	0	1	6	**10**	2	10	35	7	0	**54**	5	7	0	**12**	**122**
RR	510	7	Boy	4	5	6	0	3	1	1	**20**	0	3	0	0	1	**4**	4	5	10	2	2	**23**	1	1	1	**3**	**50**
		8	Boy	5	13	1	0	4	3	0	**26**	0	8	0	0	1	**9**	3	13	13	0	1	**30**	0	1	0	**1**	**66**
			Dyad	9	18	7	0	7	4	1	**46**	0	11	0	0	2	**13**	7	18	23	2	3	**53**	1	2	1	**4**	**116**
SS	514	9	Girl	0	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	6	20	0	0	**26**	0	0	0	**0**	**26**
		10	Boy	2	6	0	1	8	3	0	**20**	0	1	0	0	0	**1**	0	12	21	1	4	**38**	0	1	0	**1**	**60**
			Dyad	2	6	0	1	8	3	0	**20**	0	1	0	0	0	**1**	0	18	41	1	4	**64**	0	1	0	**1**	**86**
TT	686	11	Girl	2	3	7	1	13	8	18	**52**	0	3	0	2	0	**5**	1	2	13	2	1	**19**	0	0	0	**0**	**76**
	[849]	12	Girl	0	3	2	1	7	5	8	**26**	1	4	1	0	1	**7**	0	3	13	1	0	**17**	0	0	0	**0**	**50**
			Dyad	2	6	9	2	20	13	26	**78**	1	7	1	2	1	**12**	1	5	26	3	1	**36**	0	0	0	**0**	**126**
	3216			27	52	42	11	49	27	30	**238**	**1**	**47**	**1**	**3**	**14**	66	**20**	72	151	15	25	**283**	**10**	**12**	**5**	**27**	**614**

Note: for abbreviations' meaning see Table 4-15

Table 4-25 Summary of children's and dyads' behaviors towards Pleo

Behaviors		F	Rel. Fr.	Rate	Children				Dyads			
					Min	Max	Mean	SD	Min	Max	Mean	SD
Handle as an artifact		**238**	**0.39**	**4.44**	**5**	**52**	**19.8**	**13.46**	**19**	**78**	**39.67**	**22.26**
1	ArtExp	27	0.04	0.50	0	6	2.25	2.14	0	9	2.83	3.19
2	ArtMan	52	0.08	0.97	0	13	4.33	3.50	2	18	8.67	5.61
3	ArtMouth	42	0.07	0.78	0	11	3.50	3.94	0	14	7.00	5.55
4	ArtTake	11	0.02	0.21	0	5	0.92	1.44	0	6	1.83	2.23
5	ArtOther	49	0.08	0.91	0	13	4.08	3.83	3	20	8.17	6.05
5	ArtDisp	27	0.04	0.50	0	8	2.25	2.34	1	13	4.50	4.32
7	ArtRough	30	0.05	0.56	0	18	2.50	5.42	0	26	5.00	10.35
Giving affection		**66**	**0.11**	**1.23**	**0**	**14**	**5.50**	**5.25**	**1**	**15**	**11,00**	**5.25**
8	SocBos	1	0.00	0.02	0	1	0.08	0.29	0	1	0.17	0.41
9	SocLap	0										
10	SocHug	0										
11	SocCarry	0										
12	SocPet	47	0.08	0.88	0	13	3.92	4.42	1	14	7.83	5.08
13	SocKiss	1	0.00	0.02	0	1	0.08	0.29	0	1	0.17	0.41
14	SocGroom	3	0.00	0.06	0	2	0.25	0.62	0	2	0.50	0.84
15	SocTouch	14	0.02	0.26	0	6	1.17	1.75	0	6	2.33	2.25
Attempts at reciprocity		**283**	**0.46**	**5.28**	**2**	**39**	**23.6**	**10.72**	**36**	**54**	**4.50**	**11.48**
16	AttAtt	20	0.03	0.37	0	6	1.67	1.97	0	7	3.33	3.01
17	AttPres	72	0.12	1.34	0	13	6.00	4.02	5	18	12.00	5.18
18	AttOffer	151	0.25	2.82	2	25	12.58	7.01	10	41	25.17	11.55
19	AttFeed	15	0.02	0.28	0	4	1.25	1.29	1	7	2.50	2.35
20	AttCudd	0										
21	AttBids	25	0.04	0.47	0	8	2.08	2.68	0	9	4.17	3.66
Agonistic		**27**	**0.04**	**0.50**	0	**8**	**2.25**	**2.49**	**0**	**12**	**4.50**	**4.64**
22	SocHit	10	0.02	0.19	0	5	0.83	1.75	0	5	1.67	2.25
23	SocMist	12	0.02	0.22	0	4	0.92	1.31	0	7	2.00	2.61
24	SocDef	5	0.00	0.09	0	2	0.25	0.62	0	2	0.83	0.98
Total Activity		**614**	**1**	**11.4**	**14**	**83**	**51.12**	**19.61**	**73**	**126**	**102.33**	**21.86**

Note: Rows shaded indicate behaviors not observed
Note: Rates is in minutes

Table 4-26 Summary of children's and dyads' behavioral categories

Categories				Children				Dyads			
	F	Rel. Fr.	Rate	Min	Max	Mean	SD	Min	Max	Mean	SD
Handle as an artifact	238	0.39	4.44	5	52	19.80	13.46	19	78	39.67	22.26
Giving affection	66	0.11	1.23	0	14	5.50	5.25	1	15	11,00	5.25
Attempts at reciprocity	283	0.46	5.28	2	39	23.60	10.72	0	12	4.50	11.48
Agonistic	27	0.04	0.50	0	8	2.25	2.49	0	12	4.50	4.64
Total Activity	614	1		14	83	51.12	19.61	73	126	102.33	21.86

Note: Rates is in minutes

Child-Pleo Dyadic Patterns

Dyadic patterns are a combination of codes treated as individual units and assigned a code.

As can be seen in Table 4-27, 13 sequences of coordinated interaction were observed: 9 feeding episodes and 4 episodes of play. In both cases the empirical anchorage was Pleo's behavior of mouthing on which the meaningful sequence is identified and traced.

None episode of affection-related exchanges *Cuddle, Rock* or *Caress* that requires substantial contact was observed. No-affiliative behavior *Contest* was not observed, either.

The observed sequences of *Feed* and *Play* are unevenly distributed across sessions and participants: session 3 (QQ) groups up to 9 out of the 13 episodes and all play episodes took place during this particular session. On the other hand, in sessions 2 and 4 no *Dyadic Pattern* was completed. Only 5 out of the 12 participants took part actively in at least one of the episodes. The most active child was Child_3 (girl) that took part in 9 out the 13 *Dyadic Patterns*, in fact all *Dyadic Patterns* in her session were initiated by her. Just one episode was triadic (Feed_4), with both children taking part actively in the sequence performing at least one of the actions involved.

The *Feed* episodes lasted between 4 and 28 seconds and the *Play* episodes lasted between 3 and 18 seconds.

Only two episodes took place during the first minute of the session (Feed_3 and Feed_9).

With rapport to the total children bids or attempts to reciprocity that can initiate one of *Dyadic Patterns* (*Offer* in the case of feeding), these episodes represent a low rate. From the 151 instances of *Offer* observed only in 15 occurrences were followed contingently by Pleo's behavior of mouthing the object. According to our theoretical assumptions, child-Pleo contingent meaningful exchanges are considered a successful interaction, reinforcing the engagement and the bonding dynamics. Thus, we can state that the general success rate of all the attempts at feeding Pleo is discouragingly low: a scarce 10%.

Table 4-27 Observed *Dyadic Patterns*
Frequency, duration, time of *Mouth* and sequence of behaviors

Obs	Dur.	Sub	Gen	Feed							Play						
				Order	**Obj**	**Att Offer**	**Att Feed**	**Mouth**	**Release**	**Take**	**Order Time**	**Obj**	**Att Feed**	**Put Mouth**	**Mouth**	**Tug**	**Take**
OO	512	1	Girl			**X**	**X**										
		2	Boy	1	Mint												
	342-356		Pleo					345	**X**								
PP		1	Girl														
		2	Boy														
			Pleo														
QQ	496	3	Girl			**X**	**X**		**X**		1	ID Card	**X**			**X**	**X**
		4	Boy	2	Mint												
	47-58		Pleo					52			115-123				118	**X**	
		3	Girl			**X**	**X**			**X**	2			**X**		**X**	**X**
		4	Boy	3	ID Card							Train					
	99-122		Pleo					105			357-362				360	**X**	
		3	Girl							**X**	3			**X**		**X**	**X**
		4	Boy	4	Ls1	**X**	**X**					Train					
	126-134		Pleo					130			364-367				366	**X**	
		3	Girl			**X**	**X**				4			**X**		**X**	**X**
		4	Boy	5	Train					**X**		Finger					
	225-253		Pleo					230			375-393				376	**X**	
		3	Girl														
		4	Boy	6	Conif	**X**	**X**										
	262-266		Pleo					263	**X**								
RR	510	7	Boy														
		8	Boy														
			Pleo														
SS	514	9	Girl														
		10	Boy	7	Train	**X**	**X**			**X**							
	170-186		Pleo					172									
TT	686	11	Girl			**X**	**X**			**X**							
	[849]	12	Girl	8	Mint												
	482-495		Pleo					492									
		11	Girl			**X**	**X**										
		12	Girl	9	Train												
	668-675		Pleo					672	**X**								

Note. For objects description's and abbreviations see Fig. 4-31

Verbal behavior and Questionnaires

In the Appendix B is provided the verbatim transcript of children verbal behaviors during the sessions –in the original languages Catalan and Spanish-, including descriptions of Pleo performance, contextual events and conductor interventions. The verbal behavior data provides a richer framework including the local context and social situatedness of the interactive behavior data (Dautenhahn 2002).

With regard to the questionnaires, given the small number of participants involved in the study and our focus on evaluating the coding scheme and behavioral system, the results from the questionnaires have to be considered only as a complementary indicative data. The results can be seen in Tables 4-28 and 4-29.

Table 4-28 Children's answers to the questionnaire

Obs	S	Gen	Social Presence						Adjectives selection															Emotional Attachment						
			Q1	Q2	Q3	Q4	Q5	TOT	1st	2cn	3d	4th	5th	6th	a1	a2	ap	an	b1	b2	a	b	Q10	Q11	Q12	Q13	Q14	Q15	Q16	TOT
OO	1	Girl	4	4	5	4	4	19	3	18	11	19	15	17	0	2	2	0	3	1	2	4	4	1	1	1	2	1	1	5
	2	Boy	4	5	5	5	4	19	4	18	19	15	12	5	2	0	2	0	1	3	2	4	5	2	1	1	1	1	1	5
		Dyad	9	9	10	9	8	38	7	36	30	34	27	32	2	2	4	0	4	4	4	8	9	3	2	2	3	2	2	10
PP	3	Girl	5	5	4	4	5	21	4	10	12	3	11	15	2	0	2	0	1	3	2	4	5	1	1	1	1	1	1	6
	4	Boy	5	5	4	2	4	22	15	17	18	5	11	19	1	1	2	0	2	2	2	4	5	1	2	1	1	1	1	5
		Dyad	10	10	8	6	9	43	19	27	40	8	22	34	3	1	4	0	3	5	4	8	10	2	3	2	2	2	2	11
QQ	5	Girl	4	4	4	2	4	20	4	12	17	3	10	18	2	1	3	0	1	2	3	3	5	1	2	1	1	1	1	5
	6	Boy	4	5	2	4	5	18	12	9	19	3	6	15	1	1	2	0	2	2	2	4	5	1	1	1	2	1	1	5
		Dyad	8	9	7	6	9	38	16	21	36	9	16	33	3	2	5	0	3	4	5	7	10	2	3	2	3	2	2	10
RR	7	Boy	4	2	4	4	2	14	4	12	18	19	17	2	1	2	3	0	2	1	3	3	5	1	2	1	2	1	1	4
	8	Boy	4	5	3	2	3	19	17	19	6	10	18	4	3	2	5	0	0	1	5	1	5	1	2	1	1	1	1	5
		Dyad	8	7	7	6	5	33	21	31	24	29	35	6	4	4	8	0	2	2	8	4	10	2	4	2	3	2	2	9
SS	9	Girl	1	5	4	3	5	18	12	18	19	4	8	15	2	1	3	0	1	2	3	3	5	1	1	1	1	1	1	6
	10	Boy	5	5	4	4	5	21	3	8	18	5	9	19	0	1	1	0	3	2	1	5	5	1	1	1	2	1	1	5
		Dyad	6	10	8	7	10	39	15	26	37	9	17	34	2	2	4	0	4	4	4	8	10	2	2	2	3	2	2	11
TT	11	Girl	3	4	4	5	2	14	17	5	13	19	3	9	2	1	2	1	1	2	3	3	4	1	1	1	1	1	1	6
	12	Girl	4	5	5	4	4	20	1	19	13	2	4	11	3	1	2	2	0	2	4	2	5	2	2	1	1	2	2	2
		Dyad	7	9	9	9	6	34	18	34	26	21	7	20	5	2	4	3	1	4	7	5	9	3	3	2	2	3	3	8

Note: for items information see Tables 4-20 and 4-21

Note: Abbreviations: a1=number of creature elections in the first choice, a2=number of creature elections in the second choice, ap=total number of creature-like elections, an=total number of object-like elections, b1=number of positive elections in the first choice, b2=number of positive elections in the second choice, a=total number of negative elections, b= total number of positive elections

Table 4-29 Summary of children's answers to the questionnaire

Dimensions / Items	Scores	Open Responses
Social Presence (1-5) (Mean)		
When playing with the robot, I felt like playing with a real animal	3.92	
I sometimes felt like the robot was actually looking at me	4.50	
I can imagine the robot as a living creature	4.00	
I often realized the robot is not a real living creature	3.58	
Sometimes it seemed as if the robot had real feelings	3.92	
Likeability (1-5) (Mean)		
Would you like to have a robot at home	4.83	
Emotional Attachment (Yes/N)	59/13	
Do you tink Pleo can see you?	10/2	
Do you think Pleo can understand you?	7/5	
Do you think Pleo is happy if you stroke him?	12/0	
Do you think Pleo can feel sad (e.g. if he/she is alone)?	8/4	
Could Pleo be your playfellow?	11/1	
Would you feel better, if Pleo is with yu when you are at home alone?	11/1	
Biological essence attributions and guesses		
Do you think is a male or a female dinosaur? (Male/Female)	6/6	
Give Pleo a name (Open)		*Minnie, Dino, Pussa, Núvol,, Sally, Joan, Rex, Menut, Pleo, Rex*
How old do you think he/she is? (Open)		3-4 years; 2000 million; 5; 6 or 7; 8; 1; 2; 5; 8; 4; 5; 25.

4.7.3. Coding scheme evaluation

The goal of the study with users was twofold: first, from a methodological perspective to assess the feasibility of the child-Pleo interactional system proposed -and the coding schemes derived- to investigate child-Pleo interaction and eventual bonding. Secondly, from the substantial perspective to gain understanding of the dynamics of the first phase of bonding with Pleo, and more specifically on the first impression and the untrained children's initial interaction.

The coding scheme is evaluated below as an instrument in a multimethod approach that could integrate children's visible behavior data with verbal production and self-reports. The results and insights on children bonding dynamics draw from the 6 episodes analyzed are discussed in Chapter 6 *Discussion* together with the lessons learned from the study in the wild (Chapter 5).

Usability

The coding scheme described and used in this study is segregated in three sets according to the focal subject: Pleo's behavior (10 behavior units), Children behavior (26 behavior units) and *Dyads Patterns* (6 behavior units). The structure, the amount of codes and the names seem clear, easy to recognize and to remember. The use of prefixes indicating the overarching category of codes is helpful to assign codes and to remind the observer the focus in the more interpretive codes.

Granularity

We looked for a balance between the easy and straightforward micro-behaviors and the more interpretive actions with functional or social meaning. The limitation of micro-behavior based analyses has been evidenced and pointed out by the HRI community when assessing constructs such as *socialness* that cannot be drawn straight from micro-behaviors but from context-dependent purposeful activities that require broader analytical categories and interpretation (K Dautenhahn et al., 2002; Lohse, 2010).

Nevertheless, a thorough description of behavioral units is unavoidable as a first step to conform more comprehensive categories. In fact, in our system not all the micro-behaviors of Pleo's body segments and different vocalizations have been included in the coding scheme as individual units. For instance, up to 15 different vocalizations identified and described in the ethogram were combined into just two wide categories in the coding scheme: *Distress Calls* and *Amiable Calls,* according to its communicative meaning.

Our point is that fine-grained micro-behaviors could smartly be pooled in broader categories without losing the empirical anchorage but avoiding the overwhelmed time-consuming manual coding. For instance, instead of coding and treating individually each particular instantiation of epimeletic behavior they can be counted as occurrences of an overarching functional category. Maybe to study the ontogenesis of child relatedness to Pleo the more pertinent level of granularity are the functional categories in the axis of intimacy/attachment and engagement.

Concreteness

The codes in the coding scheme are social based rather than physical based because key categories in our model like *socialness* or *intimacy* cannot be grasped without some amount of interpretation. While some behaviors are clearly physically based as *Kiss,* with few room for interpretation, other behaviors can only be assigned to social or not social categories by interpreting the meaning from the child's perspective (i.e. *Handle as an artifact*). Nevertheless, a considerable effort was put to anchoring the more conceptual codes in physical-based descriptions to guide the coding.

According to our approach, Pleo's simple movements (e.g. raising one leg; moving the tail side to side) that are followed by a clear children response (e.g. *Look*!) are registered as *Funny movements* because they are communicative, while the rest of micro-movements are not registered.

Segmentation

Children's and Pleo's behaviors were video-recorded continuously during the play sessions and reviewed for coding. Early in this process we confronted the difficulty of how to segment behavior, especially with duration behaviors as petting. To stablish a reliable means of coding a distinct behavior unit we wrote indications and rules of coding (Table 4-16) that should be completed and refined in further coding scheme versions. For instance, in the case of petting we decided to count a new occurrence any time the modality of petting (e.g. scratch, caress) or the part of the body caressed (e.g. top of the head, back) or the part of the child's body used to caress (e.g. fingers, palm of the hand) changed, or if none of the changes happened, every 2 seconds.

Reliability

All the coding was done by one coder (the author). Though no test of –intra-coders- reliability has been done we can discuss some difficulties we confronted in assigning behaviors to close categories like *Mistreat* and *Rough manipulation*, where the only difference lies not in the morphology of the action but in the degree of *socialness* involved. Even though the discrimination between interactive behavior towards the robot as an object or as a social agent is necessary in our model, the classification is highly interpretative and raises important reliability issues. On the other hand, if the focus is not on the socialness of the interaction but on the intensity of the activity (actions' rates accounting for engagement) or its valence (positive/approach vs. negative/aggressive interaction towards the robot) this distinction is not as relevant and maybe categories like *Mistreat* and *Rough manipulation* could be merged.

5. A Case Study: Pleos Accompanying Children in a Pediatric Hospital

In Chapter 3 a multi-layered model of child bonding with robotic-pets was presented, and in Chapter 4 an interactional system and coding scheme were developed to analyze children interaction with a particular pet-robot, the baby dinosaur Pleo, from an ethographic approach.

In the present chapter, the theoretical framework and the observational tool are applied in a Pleo-based intervention in a pediatric hospital to accompany children and families during their stay. The main assumption is that the engaging interaction with Pleo we observed in controlled environments in the short term could be a sound base for a quality of life interventions for hospitalized children, beyond the novelty effect.

Therefore, in the present chapter the focus is on the feasibility and impact of a Pleo based intervention, analyzing both child-Pleo interaction in the wild and the dynamics of adoption and appropriation at organizational level.

5.1. Introduction

An observational study was carried out in the Pediatric Hospital of Sant Joan de Deu in Barcelona to investigate in the field the key processes in a robotic-pet based therapeutic intervention. The main research questions were: i) how the robot is interacted by children, families and staff (interactional practice), ii) whether it is integrated into daily practices in a durable way (adoption), iii) how it impacted the caring-network and its practices (appropriation), and iv) how the whole process evolved over time. The study was implemented in coordination with the hospital's Child Life and the head of team of volunteers.

As mentioned in the State of the Art (Chapter 2), the antecedents point out the particular challenges of deploying robots to accompany children in hospitals. In particular, field research in pediatric hospital arises specific ethical issues due to the sensitive nature of pediatric care context that limits both the research techniques to apply and difficult the organizational and professional adoption and appropriation (Jeong et al., n.d.). However, in the case of Pleo-based interventions there are neither physical risks nor threatens to privacy provided the small size of the robot, the smoothness of its movements and the lack of functionalities for acquiring and delivering sensitive data. The robot is usually seen as an appealing, friendly, harmless electronic toy with smart life-likeness features.

The intervention initiated with an ethnographic study where five Pleos were deployed by the research team during two months, followed by a longitudinal follow up with a young in-patient girl who kept Pleo as her *pet* until her leave. These studies was complemented by two programmed group activities with Pleo to better observe the interactive practices: a session in a playground installation called *Pleo's Farm* and a play session open to hospitalized children and their relatives. Finally, a focus group was carried out with the team of volunteers that had adopted Pleo as a regular resource to accompany children, as a consequence of the ethnographic study. The aim of the focus group was to investigate the subjective experience of adoption from the practitioners' perspective (see the timeline in Fig. 5-1).

The data obtained will be discussed in line with the proposed model of bond forming (Chapter 3). Finally, from lessons learned we suggest guidelines to design pet-robots for lasting relationships, and to manage pet-robot interventions in hospitals.

Goals and Approach

The research questions of the case study are

1. How people at the hospital –in and out patient children, relatives, clinical staff, volunteers and bystanders- interact when exposed to the presence of Pleo in the regular routines and activities of the hospital daily life.
2. Whether these interactions have a positive effect in the experience during the stay at the hospital
3. Whether and under which technical and social conditions the robotic-pet could be adopted by children and families and/or appropriated by the organization.
4. Whether and to which extent this new resource could improve children caring.

The topics to investigate are:

1. The behavior, attitudes, emotional responses and perceptions of children and other participants and hospital staff towards the robot and towards the deployment process
2. The robot role –if any- in the process of caring inpatient and outpatient children
3. The deployment process as it unfolds and the *whys* and *hows* the personnel –eventually- get involved in this deployment

We adopt a holistic and ecological multi-method approach, with preference for the qualitative methodology and the observational techniques. In our research, an specific reason to prefer direct observation in CRI than self-reporting is that there are evidences that children's reasoning about robots (e.g. the robotic dog AIBO) and the way they interact with them do differ (i.e. children assess similarly stuffed dog and AIBO, but behave differently) (Kahn, Jr. et al., 2006).

In addition, the ethnographic approach provides a rich perspective from the inside, within the context in which interaction with the robot actually occur -rather than on retrospective judgements- offers a very insightful view on the net of communication and relationships in complex social systems as the hospital (Mukherji & Albon, 2015). This focus on exploring beliefs and practices as they are shown up in the naturalistic scenario produce very valuable understanding of how the care-giving network could effectively incorporate this Pleo based new service.

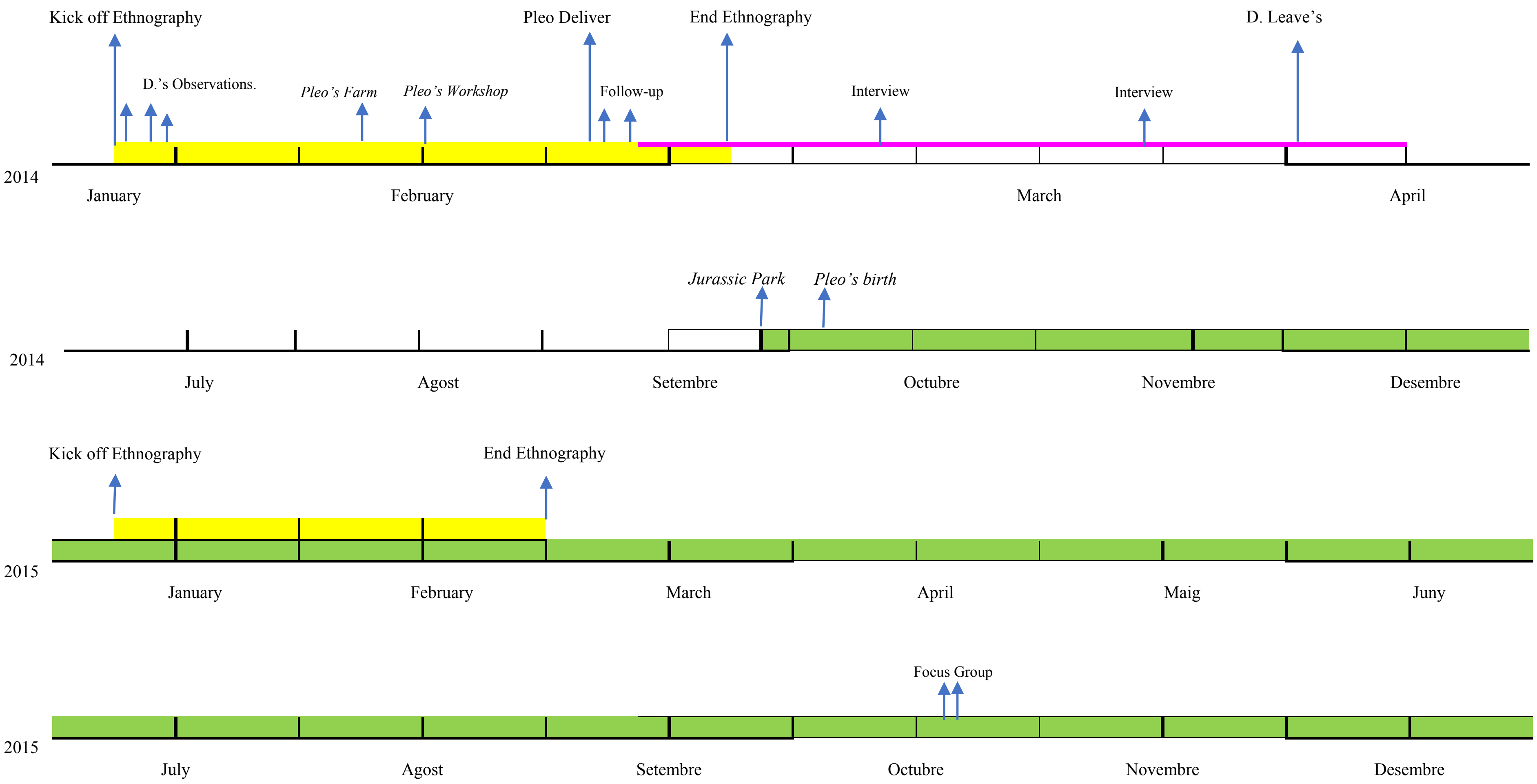


Figure 5-1 Timeline of the study

5.2. The Ethnographic Study

From January to March 2014 an ethnographic study was carried out in the hospital as the robotic pets were deployed as an innovative non-therapeutic activity, supporting the *Kid's Friendly Hospital* program, in collaboration with the volunteers' service and supervised by the Child Life. The goal was to observe as much as different situations and contexts as possible, to understand the dynamics of interacting with Pleos from different perspectives in order to gain insight and to draw recommendations to –eventually- consolidate the service.

The study was designed including the main traits of ethnographic research: immersion (i.e. the researchers become members of the pediatric hospital in some way), participant observation and the keeping of detailed fieldwork diaries, studying children at hospital "as they go about their everyday lives" (Mukherji & Albon, 2009, 85). More in detail our study features the characteristics that Pole and Morrison state that ethnographies have in common (Mukherji & Albon, 2009, 86):

- There is a focus on a specific location, setting or event.
- Within this specific location, setting or event, there is a focus on the full range of social behavior
- A range of methods might be employed –although, in general, the emphasis is on observation- in order to understand this social behavior from inside the location, setting or event.
- Data analysis involves a movement from rich description to identifying concepts and theories that are grounded in the data, which is collected in that location, setting or event.
- There is an emphasis on capturing as much detail as possible and in so doing, not shying away from the complexities of the issues in the research location, setting or event. This is viewed as more important than the ability to make generalizations.

5.2.1. Antecedents in Ethnographic Studies on Long-Term HRI

Some studies on pet-robot adoption used ethnography to explore the *hows* and *whys* of relating to artificial creatures in naturalistic environments (see Table 5-1 for a summary of selected studies). Fernaeus (Fernaeus et al., 2010) conducted an ethnographic long-term studio with six families, which were given a Pleo for a minimum of two months and a maximum of ten. Jacobsson (Jacobsson, 2009) carried out a digital ethnography based on the opinions of a blog users about Pleo. The main results are related to initial engagement due to the novelty effect, the care behaviors and the long-term disappointment effect. Even so, most of the studies identified the development of a social bond with the robot.

As far as we know, there are no antecedents of ethnographies addressed to study pet-robots adoption in pediatric settings.

Table 5-1 Ethnographic studies on social robots

	Robot	Aim and Objectives	Design / Setting/ Duration	Participants	Techniques and Data	Main Results
Fink, Bauwens, Kaplan, & Dillenbourg, (2013)	Robotic Vacuum Cleaner (Roomba)	Investigate the usage, acceptance and process of adoption 1. How the robot was used and integrated into daily routines 2. People's perception of the robot and how it evolves 3. Whether it was adopted in a durable way 4. How it impacted its environment	– Exploratory – Qualitative – Ethnographic – Long term – At participants homes Six months span	9 households	Qualitative and quantitative techniques (questionnaires) – Home visits field notes and photos or videos from the on-site observations – A 'home tour' – Semi-structured qualitative interviews audio-recorded and qualitatively re-transcribed – Cleaning diaries – A series of seven point Likert scales integrated into a small questionnaire to be filled out at each visit.	
Fernaeus, Håkansson, Jacobsson, & Ljungblad, (2010)	Pleo	1. How Pleo was interacted with and reflected upon in in a "natural" environment without constrains.(homes) 2. Obtain a better understanding of the design challenges involved in developing advanced interactive toys for everyday settings	– Exploratory – Qualitative – Ethnographic – Long term – At participants homes – Design-commercial perspective – From 2 months to 10	6 families with kids from 1 to 17 years old Total children=13	1. Clips video recorded by the families, pictures. 2. Interviews, at least 1, mostly 2, the first one after 2-3 months	Skeptical about the capability of Pleo of engaging people on the long-run

	Robot	Aim and Objectives	Design / Setting/ Duration	Participants	Techniques and Data	Main Results
Sung, Grinter, & Christensen, (2010)	Robotic Vacuum Cleaner (ROOMBA)	Understand the evolving usage patterns of domestic robotic appliances	Longitudinal field research over siix months In total, the entire study spanned more than a year, from June 2007 to August 2008	30 households	– 5 visits per household, 149 household visits – Qualitative techniques (generative Techniques) First interview: – Provide a layman's description of a generic robot – Rate knowledge of robots on a seven point Likert scale (familiarity) – Visual depiction of their ideal home robots – Open-ended questions about their knowledge of Roomba Second interview: – Expectations about this product on a seven point Likert scale. The categories of Likert scale included, intelligence, ease of use, usefulness, emotional attachment, entertainment value, and degree of impact on household. – Observation of first impression while running the Roomba for the first time – Post-running debrief + complete again the Likert scale on expectations Third: – Self-logs (cameras, scrapbook, e-mailing) – Bubble drawing – Highlighting their blueprints again to show us where Roomba had cleaned since the previous visit, ranking their perceptions of Roomba on the Likert scale, and finally checking the activities they did with Roomba from a pre- generated list, such as hacking, naming, and demonstrating to others off on an activity card Fourth: same to Third Fifth: – Provided participants with a photo of Roomba with blank boxes that had a question asking on what occasions the robot generates sound. Check list of Roomba activities focused on maintenance – Visual position or value map on two axes. Usefulness and pleasant-unpleasant – Ask for potential improvements	Advances in the *Domestic Robot Ecology* framework Implications for Design

	Robot	Aim and Objectives	Design / Setting/ Duration	Participants	Techniques and Data	Main Results
Jacobsson, M. (2009)	Pleo	Explore stories about how human-robot interaction would manifest themselves in actual real-world contexts 1. How's living with a companion robot 2. Identify significant features of people relationship with robots.	– Qualitative – Exploratory – Virtual Ethnography: content analyses from blogs and on-line forums	Bloggers in a particular blog presumably adults	Content analysis based on user-provided content collected from online blogs and forums about the robotic artifact Pleo. Posts gathered from a particular blog	Patterns: 1. Arrival and appropriation 2. When technology breaks down 3. Pleo as a socialization resource 4. Playing with Pleo
Friedman, Kahn, & Hagman, (2003)	AIBO N=182 Presumably Adults	1. Investigate people's relationship with AIBO 2. Wether they treat robotic pets in some meaningful ways as if they were animals	– Qualitative – (Discussion Forum) – Value Sensitive Design (Content analyses?) – Pilot, generation of a coding manual/ analyses of formal data		6438 spontaneous postings in online Aibo discussion forums Selected 3119 posts from 182 participants	Participants often attributed technological essences (75%), biological essences (48%), mental states (60%), and social rapport (59%) to the robotic dog. Participants seldom attributed moral standing (12%) to the robotic dog
Author's	Robotic-pet Pleo	Gain understanding in the real context of application: 1. How Pleo was interacted with and perceived upon by the different actors in children taking-care in a Hospital 2. How the robot was used and integrated into daily routines (impact and appropriation) 3. Obtain a better understanding of the design challenges involved in developing advanced interactive systems for everyday life in children hospitals	– Exploratory Ethnography – Case Study – Action-Research (?)		Gathering Data: – Participant Observation – Informal short interviews with actors – Retrospective Focus Groups Qualitative analyses of: – Researchers' in field diaries – Interviews – Focus Groups	

5.2.2. Method

The fieldwork was carried out by a mixed team of senior researchers –including the author-, engineers and graduated and undergraduate students at the Faculty of Psychology at the Universitat Autónoma de Barcelona with a sound training on qualitative research and fieldwork (Table 5-2). The technique was an unstructured participant observation while carrying out the intervention of deploying Pleos in the Hospital units, and the researchers' camp diaries and the group discussions were analyzed through a *thick description*, a description in terms of significance (Geertz, C. 2003 in Cejas, 2014).

Our research is not a *pure* ethnography at least for three reasons: we carried out an intervention to provoque changes and so we deliberately *disturbed the field*; it was not as extensive as recommended, and the role of the field researchers was more than participant observers because they carried out the intervention. On the other hand, the study shares some traits with action research: its context specific character, the emphasis on feasibility and effectiveness, and the partnership and direct involvment in the research of *insiders* (e.g. Child Life and Innovation Departament and volunteers team).

The researchers' double condition as practitioners and observers of its own practice places this study in a halfway between ethnography and an action-research. In conventional ethnography, the researchers' position usually is *detached* –in different degrees- from the events and phenomena studied. On the other hand, it is not either an action research because the focus is more in understanding the phenomena than in improving a practice, and the researchers are not *insiders* (Llobet & Moreno, 2014; Mukherji & Albon, 2015).

Table 5-2 Field research team

Field Team	ID	Genre	Background
Maria Moreno	M	Female	Undergraduate student in Psychology
Sophia Papadopoulou	S	Female	Undergraduate student in Psychology
Gemma Llobet	G	Female	Undergraduate student in Psychology
Vicenç Casas	V	Male	Engineer in Electrical, Electronics and Communications, Dog-Assisted Interventions Technician, Teacher of robotics.
Roberto Cejas	R	Male	Psychologist, Ms student in Social Psychology Research

Field notes were written or recorded immediately after each observation period and later transcribed into a narrative text by the researchers. Field notes were systematic notes and records of events, behaviors and words written in as detailed, concrete, objective and comprehensible a manner as possible.

The data obtained during the field work are:

- Author's and other researchers' field diaries during the ethnography and the longitudinal study
- Recorded informal interviews with volunteers during the observations
- Video recordings of the workshop
- Researchers' reports on key points for designing Pleo based intervention, according to predetermined topics.
- Two academic reports (Cejas, 2014; Llobet & Moreno, 2014)
- Recordings of the three focus group with volunteers
- Video recording of team follow-up discussions meetings throughout the study

In the present work, the data analyzed are the field diaries, the workshop video-recordings, the researchers' reports, and one of the focus group formed by volunteers who had taken part in the Pleo's deployment, the so called *Jurassic Park* team.

5.2.3. Fieldwork

The intensive fieldwork was carried out over 40 days during the winter 2014 by a team of five researchers who deployed a fleet of five Pleos in a daily bases in the Hospital Sant Joan de Déu, completing up to 150 hours of participant observation. 271 observations of children -ranging from babies to teenagers- interacting with the robots in different in-patient and out-patient units were described in detailed field notes. Children contact with the robot ranged from few minutes (e.g. a casual encounter in a waiting room in external consultancy) to more than seven encounters along weeks (e.g. hospitalized children in traumatology ward).

The field

Sant Joan de Déu-Barcelona Children's Hospital is one of the leading medical centers in Europe for childhood and adolescence attending annually more than 25.000 inpatient admissions, 200.000 outpatient appointments and 115.000 emergencies.

The Pleos-based intervention was ascribed under the umbrella of non-clinical services to enhancing the hospital experience, provided by the team of volunteers. Sant Joan de Déu volunteers offer a complementary care accompanying family members, promoting activities that allow the child to express feelings, communicate, relax and enjoy. Recently the hospital volunteering[25] has evolved into a more specific trained service to integrate interdisciplinary teams, often introducing appealing innovative resources such as tablets or 3D printing pens. Moreover, other complementary professional care services are addressed to improve children's experience in the hospital under the overall *Kid's Friendly Hospital Program* such as Child Life, animal therapy, music therapy, hospital clowns and art therapy. Differently from volunteers these are professional services delivered by specialists.

Figure 5-2 Pleo and a therapy dog in a hospital corridor

The Pleos based intervention was carried out in the following out-patient and in-patient hospital units (Table 5-4):

- External Consultancies and out-patient facilities: Asthma and Diabetes (2nd Floor), Neurology (4th Floor), Odontology and other.
- Oncology ward (8th Floor). This ward features a restricted playroom –*Oasis*- with two different spaces, an office with a fridge, an oven and coffee service for relatives and visits, and a play room with small tables and chairs, games and toys.

[25] https://www.sjdhospitalbarcelona.org/en/volunteers

- Neurology and Traumatology wards (7th and 5th Floors). Differently from the Oncology ward these other wards have not common spaces for leisure and children are encouraged to attend activities at the hospital common facilities such as the class room or the big general play room (*CyberAula*).
- *Rainbow rooms*: Two pre surgery play-rooms where children and relatives stay just before a surgery that requires hospitalization.
- *CyberAula*, main play room for in-patients in the ground floor. Adjacent to the class-room where in-patient children follow their school courses and separated by glass walls the *CyberAula* is a big well-equipped and cheerful room for children's leisure with home cinema, toys, library, board games, that offers regularly recreational activities for in-patient children and their families like make-up and cooking workshops.

Study Procedure

Differently from conventional participant observation in this study researchers took the role of practitioners –delivering the service- as well as the role of observers –observing and analyzing.

Before beginning the observation the research team were briefly instructed by the head of the volunteers' team to acknowledge the basic rules of the hospital and how to address patients and families, were toured around the hospital to get familiar with the field and were accredited and identified as volunteers –the same gown and badge-. The researchers deployed their service under the supervision of the volunteers head according to an agreed upon daily scheduling. Wherever asked the team explained their role as researchers investigating the feasibility and usefulness of Pleo based intervention in the hospital, attaching as much as possible to a common text. The text of presentation was:

> We are a team from the universities Autonomous of Barcelona, Technical of Catalonia and La Salle (I'm a student of psychology /I am a lecturer at the Technical University) that work with the volunteers of the hospital in a program to bring the Pleos, the small dinosaur robots, to different services and facilities of the hospital to entertain and support children. We want to know whether to play with the robots is engaging and whether the robots can accompany children. We are also interested to know family members' and hospital staff's views about the experience.
>
> This collaboration is a part of the research project PATRICIA [1] investigating new programs of quality of life, based on the company of pet robots that can make children's stay at the hospital more enjoyable (e.g. when they have a medical procedure, wait for a surgery, stay in the playroom). We want to understand if spending time with these robotic toys has positive effects such as affection and fun on children similarly to real pets' contact.

[1]Pain and Anxiety Treatment based on social Robot Interaction with Children to Improve pAtient experience. TIN2012-38416-C03-01,02,03

However, the fieldwork team members were mostly perceived by relatives and clinical staff as another specialized service to support children well-being. The researchers received a short training in Pleo *usage* and *training* and basic maintenance.

The researchers offered the service -playing with Pleo- to children using different strategies according to the context, children condition and attitude, and personal style. The only instruction was to encourage children to explore robot's interactive and playful capabilities.

Data Collection

The five researchers wrote field diaries and completed informal interviews with volunteers. In addition, the follow up meetings and the coordination meetings were recorded for analyses. In the broader sense, diaries are a series of notes that a subject write on his experiences and the circumstances that goes with them produced on a daily bases or almost a daily bases along a phase of his life. However, in this case the documents analyzed are research diaries or exo-diaries in the sense that are narrative registers written by researchers on the topic and subjects that are investigating (Riba, 2007).

In addition to the field notes and follow-up discussions, the researchers were asked to complete a structured report answering direct questions about specific issues oriented to draw guidelines for further robot-based interventions (e.g. critical incidents, recommendations to match professional expectations). The questions are listed in Table 5-9. The narratives from the five researchers' field notes were analyzed applying qualitative content analysis techniques.

Table 5-3 Observed episodes of interaction with Pleo

		Episodes						Children					
	Observers	M	S	G	V	R	**Tot**	M	S	G	V	R	**Tot**
Out-patient	Asthma an Diabetes (2^{nd} Floor)		4	1			**5**		28	8			**36**
	Ext C (3^{rd} Floor)				2		**2**				>6		**6**
	Neurology (4^{th} Floor)		4	3	2		**9**		26	27	4		**57**
	Other Ext.C.				4		**4**		2		>10		**12**
	Odontology			1			**1**			1			**1**
	Common Facilities				1	2	**3**				1	4	**5**
	Tot Out-patients	**0**	**8**	**5**	**9**	**2**	**24**	**0**	**56**	**36**	**21**	**4**	**117**
In patient	Rainbow		5		2	2	**9**		35		2	3	**40**
	Oncology W.	14		4			**18**	55		17			**72**
	Neurology Ward				2		**2**				2		**2**
	Surgery (5^{th} Floor)	1					**1**	1					**1**
	Respiratory Ward (7^{th} Floor)	1		2			**3**	4		6			**10**
	Other Wards		1			1	**2**		10			?	**10**
	CyberAula	1	1	2		1	**5**	6		8		5	**19**
	Tot In patients	**17**	**2**	**8**	**4**	**4**	**40**	**66**	**45**	**31**	**4**	**8**	**154**
	TOTAL	**17**	**10**	**13**	**13**	**6**	**64**	**66**	**101**	**67**	**25**	**12**	**271**

Note: see Table 5-2 for observers' details

Table 5-4 Summary of episodes and children observed

Wards/Units	**Observations**	
	Episodes	**Children**
Asthma an Diabetes (2^{nd} Floor)	5	36
Neurology (4^{th} Floor)	9	57
Other Outpatient Services	6	18
Odontology	1	1
Common facilities	3	5
Total out-patients	**24**	**117**
Rainbow	9	40
Oncology Ward	18	72
Neurology Ward	2	2
Surgery	1	1
Respiratory Ward	3	10
Other wards	2	10
CyberAula	5	19
Total in-patients	**40**	**154**
Total	**64**	**271**

5.3. Longitudinal Study: Adopting a Pleo

Once the ethnography provided evidence about Pleo's presence being accepted and considered in general a valuable resource by the hospital community, we decided to go a step further and to carry out a longitudinal study of Pleo as a companion and to explore the –eventual- bonding with it, what was the ultimate purpose of the research. The longitudinal study aimed to complement the ethnography providing a new scenario to observe the development of interaction over time, what is not easily captured by the ethnography that proposes a series of non-scheduled casual short encounters with different children during Pleos deployment.

The participant was a girl aged 4 (*D.* from now on) who was selected by the Child Life taking into account the girl's and her family good attitude towards Pleo, the fact that most probably D. had to stay at the hospital for some more days or weeks, the fact that keeping Pleo would have a beneficial impact not only for herself but also for her siblings, and the close collaboration and smooth communication with her parents.

At the time of the study, D. had been hospitalized for three months, and the whole family –the parents in their early thirties, two twin brothers aged 3 and a girl aged 2- moved to Barcelona to live in a flat near the hospital to be close to D. and stay together as a family. D. suffered from a medically resistant epilepsy that required a continuous monitoring and characterization of her seizures –including frequent invasive procedures- to adjust the treatment. She had to be continuously supervised because the frequent seizures came unexpectedly with episodes of a high rate up to a dozen seizures per day. She used to wear a biker helmet to prevent injuries if she collapsed. The purpose of her stay at the hospital is to stabilize the illness, to reduce the seizures and to found a customized medication. Her siblings spent almost all the day long in the hospital with her and their parents. D.'s physical and psychological condition was variable depending on the course of the illness and seizures and on the side effects of the medication that sometimes obliged her to stay in bed even for days and affected her awareness.

D.'s family was particularly well known by the staff and had been most interested in exploiting all the facilities and resources available to make children life in the hospital friendlier. The parents always appeared collaborative, taking part in the proposed activities and very grateful to any help or service.

5.3.1. Objective and Methods

This study covers 69 days of D.'s hospitalization, from the first encounter with Pleo at day 2 of Pleo's deployment until the family left the hospital.

D.'s interaction with Pleo was registered and analyzed in different moments, by different researchers and with different techniques:

- Researchers' observations during the first days of Pleo's deployment, when at least three episodes of D. interacting with Pleo took place -all of them at the CyberAula- and were registered in the field notes by three different researchers (S., G. and M.) on days 2, 4 and 7 respectively.
- D.'s attendance to two programmed activities with Pleo open to all target children in the hospital: Pleo's Farm (day 15) with direct observation by the author and another researcher not taking part in the deployment (Section 5.3.3.), and the workshop Pleo's got sentimental (day 18) that was video recorded for further analyses of children interaction with Pleos (Section 5.3.4.).
- Adopting a Pleo experience (from day 23 until D.'s leave on day 69), that unfolds through four events: delivery of Nola to D. and visit to check (day 1, author's and G.'s field notes), V.' follow up visits registered in the field notes (days 2 and 11), two follow-up interviews with parents (author) (days 21 and 39).

The relevant moments and events of the research can be seen in the timeline in Fig. 5-2.

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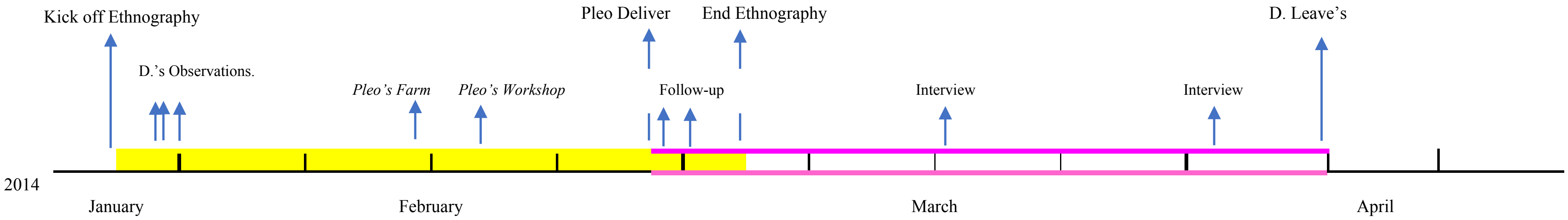


Figure 5-3 Longitudinal study Timeline.
In yellow Pleo's deployment and in pink Pleo's stay at D.'s room.

5.3.2. Casual Encounters During Pleos' Deployment

We have selected in this section extended verbatim fragments of the field notes to recreate the atmosphere and the situation, to put D.'s behavior in context and to compare with other children's behavior. In addition the fragments allow to appreciate the quality and "thickness" of researchers' diaries and the emotional tonality of the different episodes throughout the ethnography.

The quotations are translations to English from the original language –Catalan or Spanish- . Every quotation ends with an identification of the informer and of the source. The researchers are identified by a single capital letter (see Table 5-2). Children names are substituted by an initial in capital letter followed by a dot and in parenthesis a G or a B indicating the gender, sometimes followed by a figure representing children age. The text in parenthesis is contextual information provided by the informants. Text between square brackets is contextual information provided by the author.

Day 2, First encounter at the CyberAula

> With Nola (I did not take Nihao because he certainly have psychological problems after such abuse of its tail)
>
> 4 brothers 3 twins (triplets?) 4 years old and a girl 2 years old
>
> The older girl suffers from epilepsy and usually wears a helmet. The mother told me that she haD difficulty in focusing on something and cannot remain *attentive* for a long time. The whole family has been for a long time in the hospital in search of treatment and the mother seemed very interested in seeing the abilities of Pleo. D. treated fairly Nola, giving her food and touching her affectionately, his two brothers had in general a pretty wild behavior both in general and towards the robot. The little girl was very impressed by the animal and expressed it with cries of happiness.
>
> After a while the boys lost interest in Pleo and came back to the other toys. On one hand the boys were more aggressive and tried to make Pleo do funny things. On the other hand, the sisters were much more careful and affectionate, touching and looking at her [*Pleo*] eyes, hugging and putting her to sleep.
>
> Because of this nice behaviors, Nola become happy and take the position of play (with the bottom up [*invitation to play*] what really excited the girls that began to call her "Bottom! Bottom!" and another children joined the joke.
>
> [***]
>
> At that time a parent came in and asked if I could take care for her young son (1 year). The boy could not speak and seemed very intimidated by Pleo, he did not want to see her near him. He

did not get interested in anything else and I had the baby in my lap, while the girls (D. and sister) were playing with their mother and Nola.

The interest in playing with Nola was taken away by the volunteers when they began to make-up children faces in princesses, butterflies, Spiderman, etc. **[S_FN]**

Day 4, Second encounter at the CyberAula

G: Evening (17:00-19:00)

CyberAula – Nola

[***]

Down to the CyberAula with two volunteers and the Pleo. They are interested in the objective of the project, which universities come from, how long have they been in the hospital and how long we'll be there

[***]

In the main hall of the *CyberAula* a painting workshop was in progress [...]

[***]

Then they told me that there are children who have finished painting and encourage me to go to the other room. There are two children playing with cars, and another (about 5 years old) crying outside the classroom with his father. I approached them with Nola and the child stops crying and remains enraptured, but the father says that he is punished because he has fought with a boy and that I better come in to play with the children inside. I say that on Monday afternoon we will be back again. It's a pity, because the child seemed very interested in Pleo!

I come back to the two children inside. M. (6) stops playing with the cars and focus on Pleo, the other one still keeps playing with cars. He asks if Pleo makes pee and poop, and if it really eats the leaf. When he sees Pleo releasing [the leaf] instead of swallowing it seems a little disappointed. Then D. (4) approaches learning quickly to feed him and cannot stop laughing every time Pleo plays or makes some funny noise. He shows me two small dolls and I introduced them to Pleo, and I pretend Pleo eats one of them. She says "No! He is eating her! "And then I show that he has not, and I say that Nola only eats its leaves. Then comes another girl (about 6 years old) and feeds and caresses her. The boy who was playing with the cars also joins the group because the cars have been removed, and shows a slight interest in Pleo.

The volunteers tell me that it is time to close the classroom. M. kisses Pleo spontaneously, and then I offer her to the other two girls who also kiss her. I thank the volunteers to have let me in during the painting activity **[G_FN]**

Day 7, Third encounter at the CyberAula

M: 04/02/2014

Internet classroom / Oncology 8th floor (Charlie and Lionel)

C. (1.5) –D.'s sister-, J.M. (B) (2.5) D. (2-3) H. (4) –D.'s brother-, M. (G) (5), A. (G) (5), M. (G) (5), P. (G) (7), P. (B) (9)

Today I decided I wanted to try what was being with children at the *CyberAula*. When I arrived there were three or four volunteers and one mother, and outside the room there are some seats and there were two fathers, this is to say, inside the room -which is about seven times the size of the one at the oncology ward and is also divided into two spaces- there were only women (apart from the kids), and outside there were only men. Upon arrival Mary rushes into the dinosaurs and takes one and says that she knew them, in the meantime from a table in a corner J.M. (B) (2.5) who was playing with his mother watched at us and I approached them with one of the Pleos. At first, the child cries a bit because is scared but the mother convinced that is not dangerous and is very nice and calmed him down, even encouraged him to kiss her and the boy did so, and as well they end by feeding Pleo together, but if there had not been the mother I am sure that J.M. had not approached the dinosaur. In the meanwhile P. said "I want to play with the dinosaur, yesterday I played with it" and took one and put to sleep by her own without any prompt from me and in addition, she remember that the one she met yesterday was called Lionel.

Suddenly also D. and C. approach as well, I guess they are sisters. D. loves to feed them and put them in a queue, C. just try to imitate everything the other girl does. H. come as well and take one of the animal to another place and I follow him because I have seen that he is obsessed with opening its mouth, but I say not to do so (he forced Pleo's mouth open with two hands) and I show how to feed it and the right way to make Pleo open his mouth and feed it. Then M. reappears and take from D. a leaf of food and said that now it's her turn and take Charlie away to the opposite side of the room where are the video games, but D. while the other girl was unaware grabs the dinosaur and runs out (now I am really concern about the integrity of the dinosaurs).

Finally a girl called A. holds Lionel and try to put it in a truck and know how to make him mad or maybe make Pleo get upset by chance, and D. and C. have Charlie at their mother lap while a volunteer paints their faces. I'm so overwhelmed that I decide that I'd better go to the 8^{th} floor *[oncology ward*] to prevent Pleos being damaged. [...]**[M_FN]**

5.3.3. Pleos' Farm at the Teen's Room

To observe more in detail how children interacted with Pleo, we designed a programmed activity of free play with Pleo on day 16. The scenario consisted in an installation with a pet-house in wood and a wood fence that defined a nice *home* for the 4 Pleo's and a more *inspiring* scenario for pretend play (Fig. 5-4). The author and another researcher not involved in the deployment, were the observers and facilitators during the session. The aims were to carry out a focalized observation of our target group of pre-scholar children, observe them in a more controlled context in a scheduled activity and provide a scenario to highlight the illusion of pet-likeness.

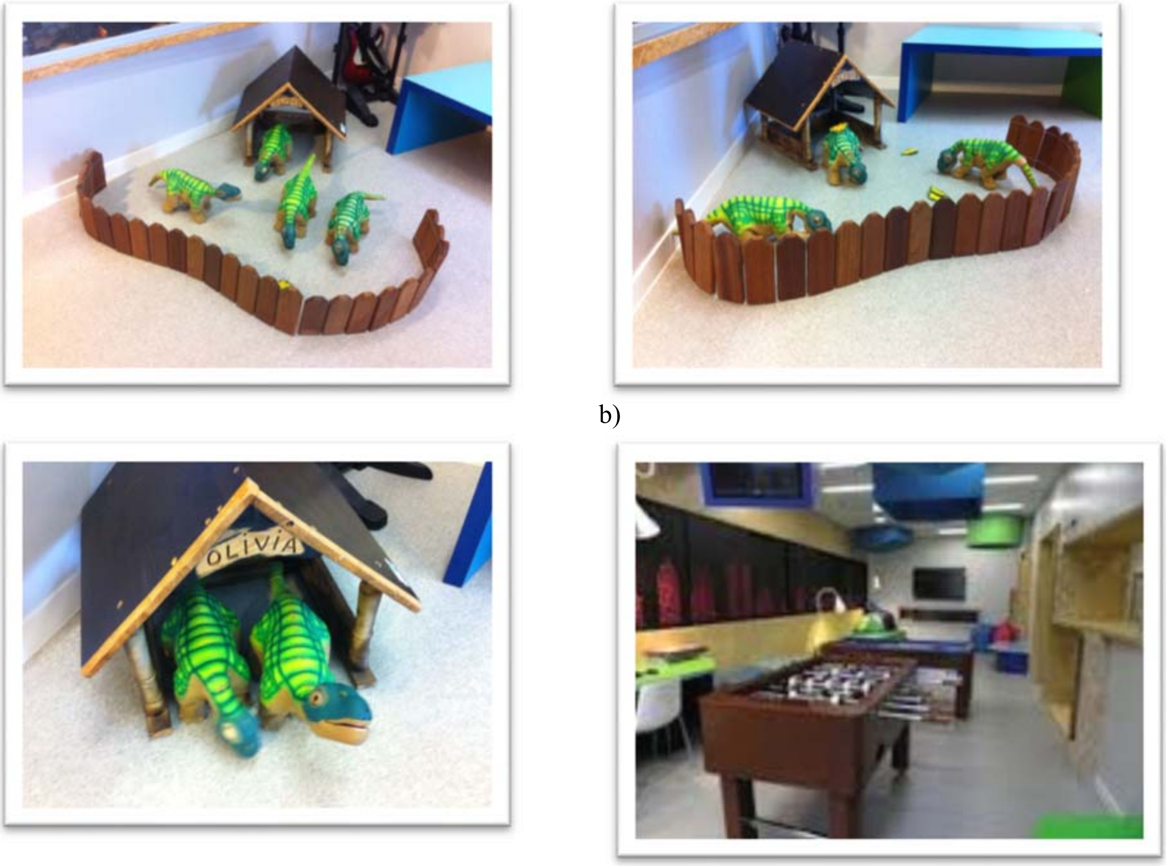
The second goal was to provide children with the opportunity of a longer session with Pleo, without the interruptions and incidences that usually happened in the regular visits in the different wards -as reported by the researchers- that limited the time every child could spend with Pleo.

We announced the activity with an open call for all in-patient children aged between 2 and 6 years old, being in-patient and their relatives. In addition, an attractive poster advertising the activity was handed out to families and stuck to the ward's walls. The call and the recruitment was mediated by the Child Life who informed the volunteers and contacted specifically with two families that knew each other, both with children hospitalized in the Neurology ward. She selected them because these families were especially fond of Pleo and interested in the experience, and have 4 and 2 children respectively in the age group. One of these was D.'s family.

Finally, only the 6 children recruited by the Child Life attended the activity. The play session was shorter than scheduled -lasted about half an hour- due to the delay of the families and the time restrictions. The attendants were D. and her family and J (G, 2)., patient at Neurology, with her brother P. (4) and parents.

The children seemed excited, approached immediately the Pleos and engaged in a continuous play. The parents showed up to be very interested in knowing more about Pleo –that they had already encountered previously- consulted the Pleo's websites and blogs with their smartphones and conversed lively with the researchers showing interest in the robots themselves and in its possible applications.

When the play time was over, we proposed the families to let the children come with us to bring the Pleos to their place on an auxiliary room in the administrative area in the same floor of the *Teen's Room* along a long corridor. They seemed delighted, took the Pleo's always in on mode and all the entourage headed to the Pleos' place. On our way, D. suddenly fall down as if she had stumbled. She was not hurt but the suspect of a seizure made the parents worried and they sat D. on the pushchair. We proceeded to the Pleo's home and turned them off to have a rest, and said goodbye to children and parents.



a) b)

c) d)

Figure 5-4 *Dinosaurs' Farm*
a), b) and c) Pleo's setting for play, d) general view of the *Young Leisure Room.* The Pleos' installation was set in the left corner at the end

5.3.4. D. at the Workshop *Sentimental Pleo*

5.3.4.1. Goals, Setting and Procedure

The aim of the workshop was to deliver the children between 6 and 10 years an amusing and instructive session to explore Pleo more in depth to satisfy their curiosity about Pleo. From the research perspective, the aim was twofold: i) to obtain video recorded data of children interacting with Pleo in a naturalistic setting to complement the narratives of field diaries with a finer analyses of children's *interactive practice*, and ii) to explore children's perceptions and cognitions about the essence and mechanisms of the pet-robot.

The workshop was designed by V. as a ludic and educative session in the frame of an engaging science lesson for young children, in appreciation to the curiosity and acceptance aroused about the robotic-pet among the hospital community. The focus was to understand the inner mechanisms that enable Pleo to *feel* emotions and change its mood and behaviors accordingly. We brought an application developed previously that presents visually and in real time the functioning of the sensors and motors, and the variation of the different internal parameters – *Feed, Mood, Emotion, Health* and *Physicality*) while the Pleo is being interacted (Diaz-Boladeras et al., 2016) (Fig. 4-2 and 5-4).

The workshop was advertised through the volunteer's network and Child Life and *door to door* in a public call and a poster that was handout to nurses and families of every ward. During the previous days the team went floor by floor to explain the activity to the nurses and to ask them to collaborate motivating and selecting children who according to their view would be able and eager to attend. Due to the changeable condition of children we were warned both by the head of the volunteers and by the nurses that it was impossible to recruit children in advance and that it was necessary to update the list and confirm attendance the very day of the workshop.

On the other hand, in the process of advertising the activity, children not meeting the age criteria showed very eager even enthusiastic to go play with the Pleos, that by that time had become very popular. After a discussion, we decided to open the activity to all children interested, because we did not consider convenient to prevent any child that showed interest from attending. Therefore, it was necessary to adapt the activity to the youngest children or to split the group to meet different interests, which was a feasible adjustment provided a team formed by 5 researchers were being present giving support to the activity.

Finally, the age and condition of the actual attendants (see Table 5-5) and the fact that children did not arrived on time made the scheduled class setting unfeasible and we changed the activity into an open session of free play with Pleos, supported and facilitated by the researchers.

Figure 5-5 Application developed to visualize Pleo's psychological states on line

Setting

The Pleo's house and fence to define Pleos' *home* was placed in a corner at the *CyberAula*. Three video recorders were placed to have different perspectives for further analyses, as can be seen in Fig. 5-6 and 5-7.

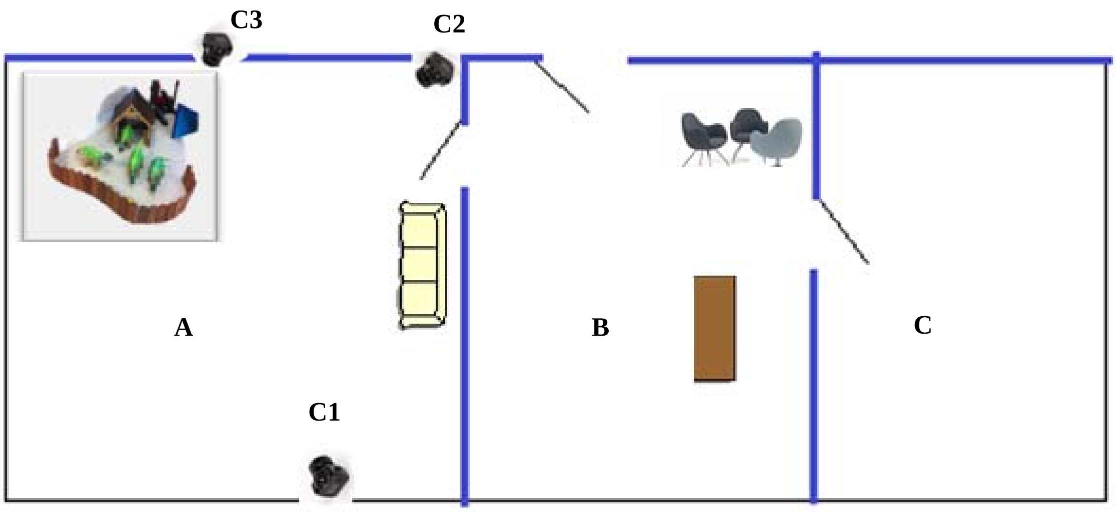


Figure 5-6 Layout of the 3 spaces at the *CyberAula*.
A the main play room, *B* lobby and *C* Class room. Setting of the 3 cameras in the play room (C1, C2 and C3). In blue glass walls.

a)

b)

c)

d)

e)

f)

Figure 5-7 Scene's views from the three cameras
Camera 1 a) and d); from camera 2 b) and e) and from camera 3 c) and f)

5.3.4.2. Workshop Development

Participants

Up to 14 children attended the workshop. Participants' ages and genres are listed in Table 5-5.

Table 5-5 Workshop's participants

Children	Gender	Age
C.	Girl	2
R.	Boy	5*
J.	Girl	2;7
P.	Boy	5*
I.	Boy	4;10
A.	Boy	5*
Ar.	Boy	7,10
M.	Boy	4;2
A.	Boy	10*
Ch.	Girl	3*
D.	Girl	4;4
H. (D.'s brother)	Boy	3
M. (D.'s brother)	Boy	3
C. (D.'s sister)	Girl	2

Researchers	Gender
S. (field team)	Female
R. (field team)	Male
V. (field team)	Male
Researcher	Male
Author	Female

Note: Ages with an asterisk are estimated.

Development

The researchers welcomed the children at the playroom as they arrived with their relatives. Before entering the Pleo's room (room *A* in Fig. 5-5) children's parents signed the informed consent to take part in the workshop and to be video recorded. In addition to children that were previously recruited, some other children that attended the room by chance or were attracted by the activity were welcomed to join the activity after a short explanation and the signature of the consent.

After a brief debriefing introducing the activity, parents were asked to stay in the contiguous room (room *B* in Fig. 5-5) or in the wide corridor separated by glass walls, to let the children play more freely and Both from the room *B* and from the corridor, the parents could supervise and watch their children, being encouraged by the researchers to feel free to get in and out whenever they wanted.

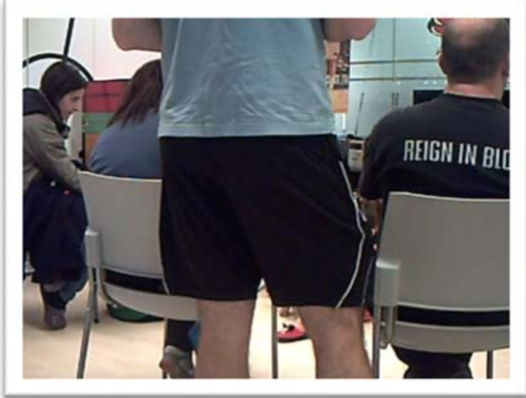


Figure 5-8 Workshop’s snapshots every 5 minutes from the video (camera 1)

5.3.4.3. D.’s behavior analyses

The atmosphere in the playroom was nice, quiet and playful, without arguments nor conflicts between children. Only one child seemed uneasy and uncomfortable and showed a plaintive behavior and did not engage in the play in spite of being encouraged by the facilitators and his mother.

Individual, collective and pretend play was observed, with facilitators taking part in different roles and styles, encouraging play, providing information and explanations about Pleo performance, or engaging themselves in the play, proposing activities, facilitating the flow of turn taking when competition for a particular Pleo aroused, praising children achievements and attempts to stablish meaningful interactions with Pleos or whatever initiative they took (see Fig. 5-8).

The coding scheme presented in Chapter 4 (see Table 4-12) was applied to analyze the interactive behavior of the dyad D-Pleo. From a total duration of 47 minutes of observed behavior only 158 seconds were not observable in detail but was still possible to discriminate between body-contact and no-body-contact behavior.

Throughout all the session, D. oriented to Pleo, holding it in a substantial contact or stablishing affectionate contact or engaging in taking care interactions as offering feed or petting.

The 41% of the time the girl kept Pleo in close contact with her body, the other 60% Pleo was not in her lap or to her bosom, but D. kept contact with other parts of the body (*SocPet, SocTouch*) or engaged in attempts to reciprocity (*AttOffer*).

The most observed point event behaviors were *SocPet* (66, applying the rule for 2 seconds segmentation, see Section 4.7.3.) *ArtMan* (35), and *SocTouch* (22). The less observed *SocHug*, *SocHit* (2), *AttFeed* (2) and *AttPres* (3).

The most frequent state behavior, were *SocLap* (15), *SocCarry* (28). In fact *Not_body_contact* (37) is a container category when no intimate body contact appear. Among state event behavior, the most prevalent were: *SocLap* (587seconds) and *SocCarry* (208seconds). None rude or aggressive behavior against Pleo was registered except from 2 hits. None elaborated interaction neither reciprocity episode were attempted based on conventional gestures or expressions and no once the girl try to get Pleo's attention. It is to be noticed that the learning stones were not available and in our previous experience, the exploration of these pieces led children to try different ways of interacting based on the pictures grabbed on the stones (see Fig. 4-33).

Only the last 67 seconds of the whole observation the girl was not engaged in playing with Pleo and this happened when the Pleos were removed and put away of children's reach to finish the session.

D. played with Pleo alone, near other children or near the facilitators. She did not avoid social contact and always orient to direct addressing to her but seem to be absorbed and enjoying playing alone just with the Pleo. She played with other children as well, mainly with her sister and brother. She engaged in play with her sister taking the Pleos in and out the kennel and the farm, putting them to sleep lying on their side, feeding Pleo while lying in another's lap, sitting two Pleo's in adjacent chairs. Some conflicts of rivalry of Pleos and Pleos' accessories arise and were easily managed by their own or with a slight indication from facilitators. D. seems weak and not fought very strongly for a Pleo or a toy. In fact she did not take a Pleo if it was not available.

She seemed always engaged, connected to the activity around her, nice with facilitators, and keeping her young sister as a reference, with some episodes of following and mimicking her.

Table 5-6 D.'s observed behaviors

Dimensions/Behaviors		**F**	**Rel. Fr.**	**%**	**Dur**	**Rate**	**Prev**
Handle as an artifact		**47**	**0,18**	**18,36**		**1**	
1	ArtExp	5	0,02	1,95		0,11	
2	ArtMan	35	0,14	13,67		0.74	
3	ArtMouth	4	0,02	1,56		0.09	
4	ArtTake	0					
5	ArtOther	0					
5	ArtDisp	3	0,01	1,17		0.06	
7	ArtRough	0					
Giving affection		**144**	**0,56**	**56,25**	**1021,60**	**3.06**	**0,36**
8	SocBos	6	0,02	2,34	58,27	0,10	0.02
9	SocLap	15	0,06	5,86	587,86	0,30	0,21
0	SocHug	2	0,01	0,78	8,43	0.04	0
11	SocCarry	28	0,11	10,94	208,60	0,60	0,07
12	SocPet	66	0,26	25,78			
13	SocKiss	0					
14	SocGroom	0					
15	SocTouch	22	0,09	8,59			
	Not_vis_full_cont	5	0,02	1,95	158,5	0,11	0,06
Attempts at reciproc.ity		**25**	**0,10**	**9,77**	**79,97**	**0,53**	**0.03**
16	AttAtt	0					
17	AttPres	3	0,01	1,17			
18	AttOffer	19	0,07	7,42			
19	AttFeed	**2**	0,01	0,78			
20	AttCudd	1	0,00	0,39	79,97	0,02	0.03
21	AttBids	0					
Agonistic		**2**	**0,01**	**0,78**			
22	SocHit	2	0,01	0,78			
23	SocMist	0					
24	SocDef	0					
Not-body_contact		37	0,14	14,45	1653,4	0,79	0,60
Disengagement		1	0,00	0,39	65,87	0.02	0.02
Total Activity		**256**	**1**	**100**	**2820,90**	**5,40**	**1**

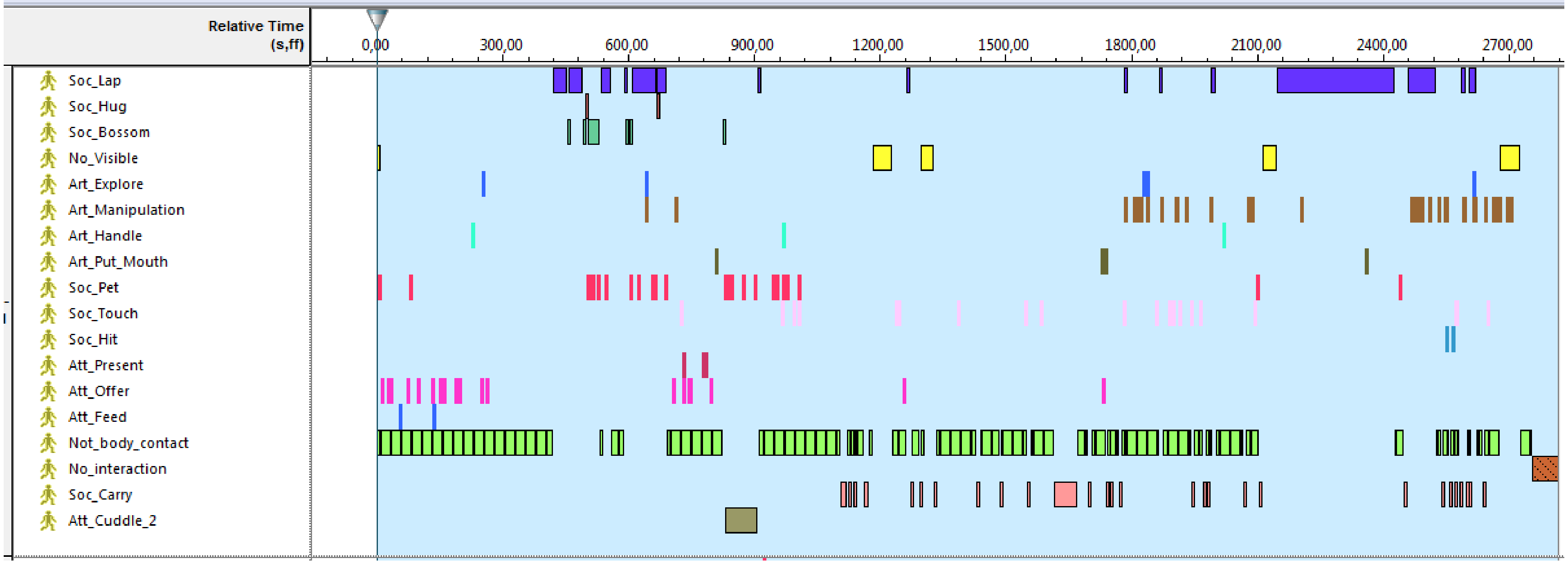


Figure 5-9 Plot of D's interactive behaviors

5.3.5. Adopting *Nola*

A complementary study of long-term interaction with a Pleo as a family animal was carried out to study the interaction with Pleo beyond the novelty effect and whether the frame of owning a Pleo had a potential to accompany children.

The Child Life practitioner proposed a family to be contacted to adopt a Pleo. The reason was that the hospitalized girl, aged 4 and her three siblings has been very excited in their previous encounters with Pleo and they have enjoyed very much the pet-robot. The children belonged to the age group Pleo has more potentiality to be engaging. The family had a very close collaboration with the Child Life due to the long hospitalization of D. that requires a close monitoring and a difficult walkthrough of interventions and procedures for months. She thought this family was a very good choice because of the fluent relationship with the hospital staff, their eagerness to collaborate, and the high probability to benefit from Pleo's presence by the demonstrated interest of D. and her family in the intervention and the frequents stays in bed that prevent her for join and enjoy other social and ludic activities.

Contacted by the Child Life, D's parents agreed to take part in the temporary adoption and an appointment was fixed to formalize the delivery and discuss the terms of the experience.

The experience lasted 46 days, during February to April, and is described and analyzed in 3 phases: delivery, follow up and closing.

5.3.5.1. Delivery

Day 1

The delivery of a Pleo was announced to the family and we arranged an appointment together with the Child Life practitioner -who acted as the intermediary between family and researchers- in her office with the whole family to officially receive the Pleo for D. When I was on my way to her office accompanied by the chief of innovation, we met D.'s father and siblings who told us that unfortunately D. was not doing well, in fact she was sick and was not able to leave her room to attend the meeting. That was an adversity for the family because lately D. seemed to be getting better and they had great expectations about a soon leave. The father seemed sad and concerned and we suggested to postpone the Pleo's delivery to D. He rejected immediately and told us that the children were very excited about bringing Pleo to her sister and that D., in spite of her late crises and her condition, was very expectant and that she could not wait to have a Pleo for her own and that she had been asking for Pleo from the very moment she was told she was going to keep one in her own room.

We had a talk to fix the frame and conditions of the experience that consisted in keeping the Pleo at their room and report the experience to us in the course of periodical interviews in about a weekly base. In addition, they will be visited time to time by the researchers –or any time under they request- just to give a hand if necessary or to attend any issue. They were told as well that they could finish the experience at any time without any kind of explanation. I gave them my cell phone number just in case they want to contact me. For the regular communication, and for any request they could have, the Child Life was our mediator, as usual.

To avoid misunderstandings and to frame the experience clearly into a *temporary adoption* we highlighted explicitly that Pleo's house was the hospital and that it was to be released back when the family leave the hospital. To reinforce the idea of D.'s ownership as a special relationship with the Pleo we pointed out that the Pleo will be D.'s pet. The father replied that this exclusivity might be a little difficult because the four children has been educated and encouraged to share all their toys and belongings.

Then we all headed to the Pleo's place to pick up the one we were delivering to D. There we found G. that help us to choose the one. We discarded the Pleos in bad condition due to deterioration for usage, and finally we decided for Nola, picked her up and took two batteries, the charger, and a bag with Nola's stuff: some leaves, the sugar cane, the salt, the tug (see Fig. 4-33) and a user's manual and went altogether –G. joined the entourage- to D.'s room at the 9th floor.

When we entered the room, D. is sitting in the bed with her mother, who told us that D. had just woke up. We put the Pleo on the bed beside her and the girl smiled. The mother said that she could not wait to have her Pleo and that she had been asking and asking when we would arrive with the dinosaur. The girl asked something to her mom in a very low voice that I could not hear, D. seemed weak, and the mother looked carefully at the Pleo and said triumphant "*It is Nola!*!" telling us that precisely D. had told her that Nola was the one she preferred to have. Both seem very happy to have been delivered the one they wanted.

We were all around the bed, the boys took the initiative feeding and manipulating the Pleo a bit brusquely what upset the father who told them to be careful. The father left to do some housekeeping, and the Child Life suggested G. teach the skills Nola was able to perform. The mother repeated several times that what really enjoy D. is petting, hugging, cuddling it and make him sleep more than any other type of interaction or activity. G. put Nola in play mode and suddenly Nola laughed noisily, and makes us all laugh, being this behavior a surprise to everyone. G. made Nola sit down, balancing on two legs and some other tricks. We discussed during a while Nola's preferences, which gadgets are to eat or not, and maintenance issues such as to be aware not to keep the Pleo working too much because it got overheating, and the way to charge the battery. The mother seemed very interested in being able to make this performance with Nola by her own. She asked us what do we want from her to observe or report and we told her everything she founded interesting or funny to discuss with us. She committed herself to take notes to report to us. After a while, we left her with her four children and Nola. G. and I left and we discussed whether to give the parents the learning stones as well or not. We decided to keep this accessories that expand Pleo's potentiality for later on and introduce them as a novelty to enhance the interest when the first excitement faded down. Before leaving the hospital, G. and I went back to D.'s room and found her asleep and her siblings playing with the Pleo on the floor. The mother told us that she had tried to make Nola do some trick, but she had not been able. We explained how to do the tricks, we said goodbye telling her to do not hesitate to ask anything they want to us and that G., V. and myself will drop out time to time to check if there is any questions or comments..

5.3.5.2. Follow Up

Day 2

V. went to D.'s room just to have a look and asked if they needed anything. He reported that the parents are very motivated and that they would try to take notes to share with us the experience.

Day 11

> 07/03/2014
>
> Today I went to St. Juan de Dios to visit D.'s parents follow up the experience of "long-term attachment." I've been talking for a while with his father (the father of another little girl with epilepsy joined us as well). [...]:
>
> D. has lost a bit the novelty effect and she does not pay as much attention as at the beginning. Probably because Pleo's evolution is slow (personality) and it is difficult to make Pleo do the performances it knows so you always keep doing the same with Pleo and this result in a loss of interest. This situation may be influenced because D. is feeling bad these days and having more frequent crises. However, when she has to rest in bed, she likes to have Nola (Pleo's name) with her to stroke it that seem to calm her down.
>
> It is hard to understand if Pleo is angry or sad or hungry
>
> It would be great that Pleo moved faster and faster and that was much easier to teach it the skills.
>
> - Repeatability: I am not sure if I have understood well, they think that repeatability and predictability when they are so young, well ... It is similar when they keep watching the same film again and again 4-5 times or more and they like it and they do not get tired.

- Comparison with the twin brothers and D. behavior: the brother who is more patient spend a lot of time with Pleo. The other one, who is anxious, get tired immediately. This is a clear example of the added value that can have a robot, in order to reprogram it and adapt to user's features, to keep them engaged.
- Anyway, parents are very happy and thankful. I was also told that other children and nurses on the unit go to the room asking for Pleo. This highlights a possible "side effect" of Pleo: facilitates and promotes human relations (as often happens with animals). [V_fn]

3 weeks from delivery. Follow up interview

This meeting was scheduled a week before but had to be cancelled due to D. health condition. D. was feeling weak and had to rest in bed during the previous week because of the medication. In addition, the three siblings had passed the flu, so we cancelled the meeting and proposed to arrange a new one when they were more relieved. Finally on Friday we confirmed our meeting on Monday morning.

When I arrived on Monday about 10.30 the whole family was in the room, an assistant was making the bed, helped by the mother. The parents were nice as always but they seemed concerned. They told me that from the day we had delivered the Pleo to D. she had had many crises and she had rested in bed. As I entered the room, M. run to the closet, opened it and took Nola, put it on the floor, turned it on and began to play. D. and her sister play on the floor with a digital whiteboard and H. watched TV. I asked how D. doing was and the mother said with a sad but cordial smile "Well, how can we be." There is an atmosphere of calm and harmony, but I see the parents more concerned comparing to my phone conversation on Friday.

Daily life in long hospitalization

D. had being in this hospital –that is far away from their home- for three months (the father told me the exact day of admission) because the girl could not be attended properly in the hospital at their place, and that was a matter of safety for the child to go to Sant Joan de Déu. They were then obliged to uprooted the whole family and move to Barcelona. Asked by D.'s day-to-day, the father immediately says there existed two types of days, the days with crisis and the days without crises. They told me that a *normal* day D. usually go to the hospital school, but that her siblings cannot go with her because they were not patients. The mother told me that any case they were allowed to stay with the children in the contiguous room. She was a teacher, she used to be their children teacher, in their town. I asked if D. liked to go to the hospital school, and the father told me that it was not very exciting because it were just three or four children attending the school because in-patient children often feel too bad and then the teachers go up to their rooms or on the other hand, the patients in good health condition that are staying at the hospital for a short time do not attend the school either.

Talking about the regular activities and routines in the hospital, he explained that on Tuesdays there was music, they come to the room and Wednesdays the dogs were in the next building in psychiatry and said it is very cool. Once the trainers made a dog *feign* a crisis lying on the floor, to explain D. what happens to her when she have a seizure. Other days, on a rotating basis, different workshops and activities were scheduled: make-up, cooking. Monday afternoons were not very exciting and they went to the play room at the outpatient facilities and to the big slide. Sometimes they leave the hospital and go to a large house, right beside the hospital occupied by a community of families that allow them to go in and enjoy the garden. They said that children loved this court, it was like a jungle, with trees, pretty wild, with swings, slides, and a playground: "*It's a dream for the kids"*.

While we were talking, two doctors entered the room to visit D. and I waited outside. When the doctors left they come to me again and the father explained to me the conversation about Pleo he had with *the engineer* (V.) The news were that Pleo now walked and also made steps backward. We come back to the different activities and I asked if their kids had other little friends. They said that they had never had a lot of friends, maybe because they were four of them. He pointed out that the two girls got along very well, and that D. has always been her older sister, teaching and protecting her siblings. At that moment the girls played together going in and out of the toilet. Suddenly a nurse looking very frightened rushed into de room followed by other two nurses. The parents said that everything was alright, but apparently someone had pushed the emergency button in the toilette. That were the girls that had pushed the button. Parents apologized, the nurse said very empathetically that was nothing to worry about, but they had been alerted, provided the girl was in the room, meaning that they thought D. had an emergency. The parents scolded gently the girls, the nurse also very nicely and comprehensive disconnected the alarm and left. I remarked to the parents that has become clear that the system worked perfectly. They take the opportunity to praise gratefully and sincerely the hospital staff.

Coping with the illness

Throughout the interview it is clear the exceptional situation of this family. As *veterans*, they seem to have more freedom and fewer restrictions on his life in the hospital, and in some cases enjoy certain benefits that they appreciate like a clear demonstration of the hospital staff sympathy and concern with children's and families' needs.

The previous Sunday they went to the beach and had lunch with some friends. But suddenly the girl had a crisis, explained sadly the father, remembering how they were enjoying the day and how sadly it ended. Until then there had been a whole week without crisis but suddenly on Sunday appeared again. Then I understood the father's optimism on the phone on Friday and that shift of mood I noticed on Monday.

They considered that D. dealt with all the situation pretty well, that she was brave, sensitive and collaborative: "*She is a saint"*. But they have a situation when the crises appeared, meaning up 10 or 12 in a day. It is a hard time as well when she has to have an intravenous line and rest in bed. He had to pass through hard procedures like electroencephalograms, spinal punctures, MRIs. Even a test that involves inserting a wire into the eye, there was also quiet without complaining. They seemed very proud of her and her unusual maturity to accept and endure this painful and stressful situations, where parents sometimes are not allowed to stay with her like in magnetic resonances.

Pleo and pets

I pointed out that maybe in this situations of procedures Pleo could accompany her. They agree with me but they think about situations where bringing Pleo could not be possible, for instance in punctures because the child should stay immobilized and in electroencephalograms either, because children has to sleep during the procedure. The father said that now Pleo is nice, lively, and more active, but that perhaps these changes are not noticeable for the kids, and that Pleo is boring until it shows more active. He said that once he was able to make Pleo do *balance* lifting one front leg and one rear leg (Fig. 4-13). I replied that that meant that they had managed to make Pleo learn an order. The mother seems a bit skeptical and said that she had never ever succeed in making Pleo perform a single trick, hard as she had tried. I ask if D.'s perform as the owner, and they said that might be, but they are very clear that everything must be shared and that Pleo belonged not just to the whole family but to the whole ward and that they were receiving a lot of visits from children who wanted to play with Pleo. They explained that a family in the 8th floor (oncology) bought one and had it in the room. They disclosed that they were worried about Pleo being stolen while they left the room without attendance and that they did not want to bother the nurses with this issue. I tried to reassure them and make them understand that they have nothing to worry about and that if eventually something happened to Pleo that would be never their fault and would be assumed by the research team.

The family had never had pets because of they did not want to have a dog unless they could provide the right conditions for its wellbeing and so they did not want to have a dog in their flat.

They once had a rabbit at school, but just for a short time because there was a child with allergy. She added that that would not have happened with a Pleo! She added that some people would like robots because they have not to worry much about and when got tired they just shut it down and that maybe even some parents would like their children to have such a turn off button. The father explained that he had always had hunting dogs in his country house, so different from a family dog because their hierarchical character, the importance of marking the boss, the process of training. He seemed to really like dogs and even to miss them.

Regarding the difference in the attitude of each child with Nola he said that M. was who spend more time with it, H. just for a while and quickly lost interest, but that it was the same with everything, that he got tired very soon, he had a lively imagination, very creative, and he entertained himself with anything, and he did not even need toys.

Incident

During the interview D. had a seizure, falling to the floor. She did not hurt badly but burst into tears. The parents reacted very quickly, the mother hugging and comforting her and both seemed very concerned. The crisis of D. changed completely the climate in the room. The mother told the father that D. had probably pain for the hit. After a short while D. calmed down and resumed her play with her sister, close to the toilette. Apparently D. did not require any special attention, but there is certain tension, parents got serious. I closed the interview and they finished remarking that Pleo's mood should be more evident and more predictable in terms of action-reaction, easier to teach some skills so children could themselves give orders and train it. They also remarked that when Pleo is on a bed, its functions are limited.

A volunteer got in announcing the mobile library and offering the kids borrowing some books. They all seemed very excited and got out with their mother. I was saying goodbye to the father in the corridor, while their mother was choosing books with the kids. The father made me notice that D. has chosen a dinosaur story. The father said he thought that we were going to speak about Pleo like with the engineer, but that we finally had talked about other things as moods. I replied that each of us had different perspectives to understand how Pleo could help to support the children in their day to day in the hospital. We said goodbye and I told I would contact them in some days to have another talk about the experience.

5 weeks from delivery. Second follow up interview

I headed to the room, where was the whole family. D. was in a wheelchair with an intravenous line and all three siblings on board, the mother walked the children up and down the corridor. The father was in the room, I talked with him who seemed to be -as the mother said- in charge of Pleo's follow up. We talked for a while and told me that D. has hardly played with Pleo lately, and M. just a bit. They are now very excited and engaged with a tablet that M. wan in a drawing contest and this is what they are fonder of by the moment because there is a big amount of games and new activities to do with it. Talking about the abilities to teach Pleo I told him that if he wanted I could pass to him the manual with the directions to teach Pleo some tricks, like the ones G. made Nola perform the day we delivered the Pleo. I said goodbye and told that I would come back in some days just to check and to remind them that if they preferred we could pick up the Pleo and finish the experience at any time. A couple of days later I sent the brochure with Pleo's tricks to the Child Life.

5.3.5.3. Close Up and Farewell

6 weeks from delivery.

The Child Life told me that D.' had left the hospital and come back home. The experience is then suspended, and in the case that D. came back to the hospital we could discuss whether to resume the experience or not. One possibility was to wait and see if eventually D. or her family request the Pleo. The Pleo's was left in *custody* at the hospital waiting for new missions –if any-
.

5.4. *Jurassic Park* Experience Evaluation

As a consequence of this first deployment, the volunteers received a donation from a patient's family of four Pleos for the oncology ward. The hospital asked the research team, -in particular V., the engineer more skilled in *training* Pleo and with a background in animal assisted therapy- to train a group of volunteers as Pleo's *experts*, in order to create a *specialized unit* inside the volunteers team to bring Pleos to children regularly. This service was referred as the *Jurassic Park*. We can say that at that moment in October 2015, the Pleos officially joined the team, about six months after being deployed by the research team in our first ethnography (see the timeline in Fig. 5-1). Pleos were given a name, were *personalized* with an identification bracelet –the ones used for patients-, a kennel was arranged in the volunteer's office, and a very cute pet-carriers were bought for each of them, to be carried around with more *dignity,* what can be regarded as a token of respect both for the donators and for the Pleos.

A second study conceived to observe how volunteer's personnel used pet robots in their regular assistance to children (i.e. the technology appropriation process) was designed and carried out on January to March 2015. However, the designed technique of observation –shadowing the volunteers while they performed their service- did not meet the expectancies of the personnel, and finally the research team adopted a more active role in the intervention. In this second study robots were extended to two more services: the Day Care Hospital –where chronic disease out-patients receive treatment- and the Ambulatory Surgery Unit. The results of this second ethnographic studies are not systematically analyzed in this dissertation.

5.4.1. Objectives

We designed a series of focus group with the volunteers, belonging to two groups: volunteers that had been members of the Pleo's team –a group that works with Pleo regularly- and volunteers who had not worked with Pleo. The main objective was to explore the volunteers' experiences with caring children and with deploying Pleo as a regular resource in their practice, as well as their experience with the process of appropriation by the organization. The emphasis was put on the subjective experience and their views on the feasibility and effectiveness of such intervention and the way it had been implemented.

Four focus groups were scheduled, two with volunteers that used Pleo in their regular practice and two more with volunteers that did not. Due to the small group of volunteers using Pleos regularly and to the difficulty to group the volunteers together in a session, one of the focus groups with Pleos' team was cancelled. In this work we only analyze the focus group of volunteers that deployed Pleo regularly.

5.4.2. Participants and Context

Five volunteers participated in the meeting, two males and three females. The group included only volunteers that belong to the *Jurassic Park* team, that is to say that were assigned to this group when the Pleos were incorporated as a new resource, regardless if they have or have not finally adopted the Pleo on a regular bases. The assignment to this team was outlined by attending a brief session of training on Pleo's use with one of the researchers, before the intervention. At the end of the session the head of the volunteers team joined the group though she was not been called to take part.

The recruitment was done by the head of the volunteers team, according to the information provided by the researchers to be sure that every participant was debriefed identically. The suggested text to be sent by e-mail by the head of the volunteers' service was:

> Dear X,
>
> As you should already know we are cooperating together with the universities Technical of Catalonia, Ramon Llull and Autonomous of Barcelona in innovative care programs for children in the hospital based on technological systems. The aim is to design these interventions in the best way to be truly useful and effective.
>
> That is why we request your collaboration by participating in a discussion group -a single session- with other staff with a background in hospitalized children attention.
>
> The session will take place at the hospital on September X, and aims to share and discuss the experiences and opinions on children care. The duration of the session will be about an hour and a quarter, in no case will extend over an hour and a half.
>
> The session will take place on X to X pm in Room X.
>
> Thank you for your help. We are at your disposal for any further clarification

5.4.3. Setting and Development

The meeting was chaired by Dr. Miquel Doménech, with a sounded experience in qualitative techniques and in technologies for health and wellbeing research, with the help of the author as assistant.

According to our objectives, seven questions were used as guides for the focus group discussion. However, this questions with the exception of the first one -a breaking the glass question- were not formulated literally or were not formulated at all when the content was spontaneously addressed by the group.

The session lasted 80 minutes.

Table 5-7 Focus group questions

1. What is the place and the mission of volunteers in the hospital caring network? What is the particular contribution to hospital goals? What is the meaning of your job?
2. How was the introduction of Pleo in your service? How do you feel about it?
3. Whether and how this new resource have changed your practice? How does Pleo fit in the previous resources, routines? Does Pleo contribute especifically to any beneficial effect differently from other resources?
4. How do you feel about this new resource? To which extend that matches your aspirations as an agent in the caring network? Have your views towards and practice with Pleo changed through out the experience?
5. How well does Pleo fit other staff (nurses, doctors) expectancies and tasks? Have they showed interest/involvement/reluctance?
6. What are your strategies for introducing this new resource in your dayly practice?
7. Is this new resource beneficial? In which cases, in which units, to which extend? Which are the inconveniences, limitations and difficulties?

Table 5-8 Participants in the meeting

Participants	**ID**	**Genre**	**Age**	**Background**	**Referent Assigned Unit**
Chair	CH	Male	55		
Assistant (Author)	ASS	Female	55		
Volunteer	M1	Male	59	Bank (retired)	Oncology
Volunteer	M2	Male	65	Priest	Critical Care
Volunteer	F1	Female	54	Administrative	*Rainbow Room*
Volunteer	F2	Female	75	Administrative (retired)	*Rainbow Room*
Volunteer	F3	Female	55	Administrative	*Rainbow Room*
Director of Volunteers	F4	Female	*60*		

5.4.4. Thematic Analyses

A thematic analyses was carried out aimed at identifying the key contents in the group's discourse. The analyses was focused on information and other communication dimensions are not analyzed in detail. The methodology and the findings are analyzed and discussed together with the data from research diaries in the next section. The main themes addressed are summarized in Table 5-9, and a report with the main findings is developed in the Section *5.5.1 Pleo's deployment*.

5.5. Findings

The findings of the case study are discussed in two blocks: Pleos' deployment and the longitudinal study of owing a Pleo in the hospital.

5.5.1. Pleos' Deployment

This block encompasses i) the first experience of a Pleo-based intervention in the hospital carried out by the researchers' team and ii) the volunteers' *Jurassic Park* intervention, carried out by the volunteers, starting 6 months after finishing the first Pleos' deployment by the researchers' team, and to date.

We analyze three sources of data: researchers' field diaries, researcher focus reports and the focus group of volunteers. These three sets of data are different in perspective and nature, and separated in time. The field diaries (FN from now on) are narratives from the notes taken by researchers just after every session on a daily bases about everything they found interesting from the open perspective of an ethnography. Researchers were *outsiders* but they were as well delivering the service so they were more than participant observers, they were practitioners whose innovative practice was observed and reflected upon by themselves while delivering the service. The focus reports (R) content researchers reflections and insights on predetermined key topics proposed by the author emphasizing the feasibility and effectiveness of the intervention. These reports are retrospective critical formulations from and about their own experience and in this sense are closer to the kind of reflections obtained in the focus group.

Researchers' focus reports are similar in its nature to the data obtained in the focus group of volunteers: critical views of practitioners on their own practice. In the case of researchers with an emphasis on *understanding* –what, how, why- and in the case of the volunteers with an emphasis on *effectiveness*.

One important difference between researchers' and volunteers' information is that researchers adopted the role of practitioners for 40 days and wrote the diaries on the fly and the reports just at the end of the observation, while the volunteers in the focus group (FG) talked about their experience after one whole year of using Pleo as a regular resource for accompanying families.

Another difference is that while the researchers were outsiders entering the field at the same time they delivered an innovative service, the volunteers adopted the resource as a new way to fulfil their regular work in the organization.

However, researchers and volunteers shared the same role of practitioners talking about their experience of bringing Pleo to accompany children, what we consider justify a joint analyses of the data, indicating always the source of the opinions.

We performed a content analysis on these data (FN, R and FG), following a procedure in between the conventional and direct content analysis method as described by Hsieh (2005). We consider our analyses both close to directed content analysis and to conventional content analyses because "prior research exists about a phenomen that is incomplete or would benefit from further description" (Hsieh, H. F., 2005). We think this is the case of this study, having a tentative framework on children-Pleo interaction formulated in prior research (Díaz et al., 2011; Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012; Kahn, Jr. et al., 2006; Pitsch & Koch, 2010) and elaborated in the present work (Chapter 3). Therefore, in this work the content analyses is "guided by a more structured process" than in the naïve conventional approach, with the goal to extend conceptually and explore the boundaries of the tentative theoretical framework.

On the other hand, this study is nor a validation or confirmatory research but a study to gain insight and understanding starting from a conceptual background that accumulates a considerable amount of research.

In particular, the steps of the process of analyses were:

- Reading all data repeatedly to achieve immersion and get a sense of the whole
- Then reading word by word in a literal sense and highlighting the exact words in the text (capturing key thoughts or concepts) reading and re-reading the transcripts
- Making notes, writing down impressions, reflections.
- Grouping and classifying data into categories, the labels of codes emerged –inspired and organized as well by the model.
- These labels (still coming directly from the text) become the initial coding scheme.

The final axes of content analyses are three: i) *Child-Pleo interaction* including first impression, interactive practice and emotions towards Pleo; ii) *Collective gaming* with Pleo that encompasses the behaviors of the different agents of the caring-net taking part –or not- in the experience of playing with Pleos, and finally iii) *Serious Pleo*, that focus on the eventual health and wellbeing related effects on children and their close environment, on the professional practices of clinical staff (indications of appropriation) and finally on maintenance issues and recommendations. See the complete axial scheme in Table 5-9.

Table 5-9 Scheme of thematic analysis of researchers' and volunteers' reports

Category	Subcategories and Behaviors		
A. Child-Pleo Interaction			
A.1. First Impression/ Emotions towards	Attraction	Wonder	
		Curiosity/Interest	Ask, Guesses, Technological interest
		Social Rapport	Tenderness, affection
		Enjoyment	Like, Delight, Excitement, Laugh
	Caution/Rejection	Fear	
		Shame	
		Rejection	Depict
	Indifference/Disinterest	Ignore, Give up	
A.2. Interactive practice	Substantial contact	Hug, Cuddle, Press to bosom	
	Giving affection (physical)	Pet, Kiss	
	Feed		
	Other		
	Mistreat/Misuse	Force feeding	
	Disengagement	Give up after interacting	
	Talk to Pleo		
A.3. Attachment	Individualization / Personalization		
	Soliciting		
	Searching		
	Glad to see again		
	Missing/ Sorry for separation		
	Memories/story		
B. Collective gaming			
B.1.Parents and relatives	Child-oriented	Facilitate, Encourage, Praise, Mediate, Reassure	
		Make-up a story	
	Play-oriented	Enjoy, Talk about, Interest, Questioning,	
		Physical interaction, Talk to Pleo	
B.2.Volunteers	Facilitate		
	Regulate	Give turns, protect, mediate conflicts	
	Demonstrate		
	Explain	Biological/social	Interpret moods, needs, feelings. Make up a story

		Technological
	Praise/Encourage/reassure	
	Mediate	
B.3. Nurses/Staff	Interest/Social rapport	
	Praise/Encourage	
	Play	
C. *Serious* Pleo		
C.1.Health related effects	On Children	Alleviate anxiety
		Distract/ Entertain
		Cheer-up
	On children with Special Needs	
	On Families	Alleviate anxiety
		Distract/Entertain
		Cheer-up
	On Child-family	Positive impact
		Facilitate communication
C2.Professional compatibility/value	Interest	
	Acceptance	
	Regulation	
	Taking Advantage	
	Requesting	
C.3.Maintainance issues	Autonomy	
	Deterioration	
	Other issues	

The findings are organized according to the content analyses system. Every excerpt are quotations from the field notes and from the focus group transcript. The quotations are translations to English from the original language –Catalan or Spanish- . Every quotation ends with an identification of the informer and of the source. The researchers are identified by a single capital letter (see Table 5-2) while the respondents in the focus group by an M or F -male or female respectively- followed by number (see Table 5-8). Regarding to the sources, FN accounts for field notes, R for researchers' reports and FG for focus group. Children names are substituted by an initial in capital letter followed by a dot and in parenthesis a G or a B indicating the gender, sometimes followed by an underscore and a figure representing children age. The text in parenthesis is contextual information provided by the informants. Text between square brackets is contextual information provided by the author.

Inside the three overarching categories, a series of key findings are elaborated. Discussion of each key finding begins with a bulleted list of the major themes that were reflected in the focus group discussion and in the researchers' production. This is followed by an expanded descriptions of practitioners/researchers narratives about their perceptions and experiences. Excerpts from the three sources and the actual words used by participants are integrated into these narratives to provide the reader with a greater understanding and appreciation of the ways in which Pleos' deployment was experienced, understood, and talked about by participants.

5.5.1.1. Child-Pleo Interaction

Key Topic 1: First Impression and emotions towards Pleo

- Children immediately feels attracted by Pleo
- Many reasons to feel appealed by Pleo
- Some youngest children show initial wariness
- Cases of rejecters
- Practitioners, relatives and peers support reluctant children approach
- Teenagers' ambivalence: attraction vs. embarrassment

Attraction

In general the researchers reported a positive attitude of children towards Pleo at the first glance and that Pleo easily catch children's and adults' attention and attract their interest.

> Once they see how it reacts and confirm that it is inoffensive, they take fast confidence and they pet it, take it and touch it everywhere. The most common behavior is the curiosity and therefore the willingness to touch it. The less common is fear. [V_R]

> (*External consultancies*) We decided to stay at the 4th floor. Just turning on the Pleos a lot of children came to us. We were placed at different areas on the floor and each one was with a little group of kids. I was with 4 or 5. All of them were astonished with Charly. [G_FN]

> Pleo immediately attracted the attention of most kids (in fact, I would say that some child didn't come closer, intimidated by the presence of so many children around Pleo) and they stayed around him all the time... most of them did not come back to what they were doing previously. [V_FN]

Very often Pleos elicit emotions of enjoyment, amusement, high excitement and delight:

(*Oncology / B_16*) he didn't stop calling her mother to come to see him (he did gestures because apart to use a wheelchair he have difficulties with language and he hardly speaks, though he understands everything you say, even in Catalan). Although he is a teenager, I think he is the one I have seen enjoying the dinosaurs the most... his happy expression was unbelievable. [M_FN]

(*Oncology / B_16*) He was excited to have Charlie for him (for the sister too, so occasionally we have to make peace...). [M_FN]

[*Oncology / G_5*] And there I found him with X. who screamed of joy when he saw the pair of green characters with me. [M_FN]

With teenagers usually often is observed an approach based on technological curiosity and interest:

Then you tell them: "Do you like robots?" and all the eyes get wide-opened. Is then when I go to pick it up. When the kids are teenagers, these, if they want to study electronics, some of them explain to you what they want to do in the future, and then when they see it they are amazed. Then, they grab the phone and they start to take pictures. [F1_FG]

Caution/Rejection

The exception to the spontaneous interest is the reaction of reluctance to approach Pleo or a withdrawal or rejection due to wariness or fear.

Only once a child was so afraid of Pleo that, despite trying to convince him, he finally didn't want to caress it. [V_R]

(*Four years, oncology*). Not only didn't want to play, but if he saw it close to him, he stood and pushed it away and gave a hard look at it. [M_R]

Youngest children are more prone to be scared by Pleos' appearance, movements or sounds. The strategies to cope with initial wariness supporting the child, to persuading them verbally that there is no danger, showing how to behave with Pleo or using the adult, the researcher or even another child as a mediator. We notice here that the strategies to make scared or reluctant children engage with Pleo involve volunteers but also relatives, other adults, and peers in an effort to help the child to overcome their fears and to join the game.

[*Do they approach spontaneously?*] Sure. Although some children are afraid of touching it, certainly they do it just once, and quickly with the facilitation or with a parent or a volunteer [S_R]

There was a 1 year old girl, M. who has been observing Pleo for a long time and was playing next to us but refusing to touch it because she was afraid. But it doesn't excluded interaction because she used me as a mediator giving me the eating leaf to give it to the dinosaur. [S_R]

(2 years oncology) N. is afraid of Pleo and the adults encourage her to touch it but she doesn't want to. Finally A._B (five years old) teaches her how to treat it and the things she can do with it and then the girl lose her fear. [M_R]

If you hand it to them "that way" a lot of children reject it. "Here you are", no way. Then I seat next to him/her to talk about el Barça, Madrid, the school… [F3_FG]

You accompany them, when you hand it, you accompany them. [F2_FG]

So, when I pet it and he sees that of course, it's no harm, on the contrary… Then you see they look at as asking: "May I?" Then I approach it closer and closer. [F2_FG]

[...] and they have lost the fear in a while, more or less quickly depending on the collaboration of the parents (picking it and motivating the kid) or the volunteers. [V_R]

Motives of wariness

Children's fear seems to proceed from an attribution to Pleo of internal states, a feeling of danger because of Pleo's potential aggressive intent, potential threatening actions such as biting. Sometime this fear is enhanced by the intervention of adults and their willingness to create and *agentive illusion* to make the play more realistic and fun.

(one year, oncology), N. was frightened because her mother told her that Pleo had bitten her and he was scared. [M_R]

I. (13 years old, oncology) is also afraid of Pleo's noises, especially at the beginning, or of being bitten [M_R]

... some of they are afraid with the movements. They aren't used to moving toys. So, when it turns the head they start crying. I warn then before. [M1_FG]

(Oncology / B_16) O., for example was afraid but he was wishing and trying to touch it all time; in fact he treat it if it was alive and it could bite him; he put his hands closer and then when Pleo move the head next to him he frightened take his hands away. [M_FN]

(At Rainbow Room) There is a lot of fear, too. The mother tries to motivate her to play, playing with Pleo herself, but the girl just approach when the parents hug it. The mother said that she is afraid of everything that moves. [S_FN]

Embarrassment

Sometimes the reluctance to approach and to engage in interaction comes from a feeling of shame for being involved in what they might consider a childish game of *pretending* treating the robot like a real pet and involving emotionally with it to some extent.

> After a certain age (9-10 years approximately), children are more embarrassed to have some kind of interaction with Pleo (position of a baby in their arms, for example). [V_R]

However, almost in all cases the respondents consider that they are really interested in them feel ashamed to let others –family, friends- know. In the reports seems clear that it was a case of *social desirability* and occur always when the teenager was in the presence of someone else, being friends or relatives.

> Others, ostensibly interested, rejected Pleo because is “for kids” and doesn’t fit their age (more than 13 years old). [S_R 4]

> I introduced it to a 17/18 years old boy, and no, no way because the girlfriend was there with him. Afterwards he called me: “Listen, I want it”. Another day the girlfriend came and I told her: “Listen, you boyfriend wants it”. [M1_FG]

> With grown up kids, the problem is when the mother is with them and says: “No, he/she is too old”. I always say: “At least touch it, pet it because it just wants to say hello and we’ll leave”. Normally, the boy starts to interact and the mother remains “that way”. Normally mothers act as a guardian. “Don’t bring this to my boy”. Where I was rejected was with three girls kind of old though, I think that they wanted it, but… [M1_FG]

> With teenagers, boys do. First is a No: "Don’t, don’t, where are you going with this?" I insist a little, and say: "It won’t eat you”. Then I put it on him. When they see it they remain “that way” and they give it to the mother: “Take it, take it”. Quite often, when I go to the other bedroom, I come back and I see him with the dinosaur and the parents taking pictures. Remove the barrier first, break this teenager shame and then they’ll accept it. M1_FG]

Rejecters

Very few children rejected absolutely to play with Pleo. The respondents report these situations only when asked explicitly, like very exceptional events.

> *(10 years old, 7th floor)* S., whose mother pushed out of the bedroom pushing her wheelchair [...] and she not only did not pay any attention to the Pleo I put at her lap but neither he talked to me and she asked her mother to bring her back into her room again. [M_R]
>
> C. *(7 years old, oncology)* doesn't show any kind of interest in Pleo, she actually reminds me of S. at the seventh floor; she had the dinosaur at her feet and she didn't make any gesture to approach, to touch it, and I couldn't convince her, neither a volunteer to play with it. She asked her mother to come back to her room; even when her roommate had two Pleos she didn't even looked at them. [M_R]
>
> There has been only one case where a child didn't want to touch it. [V_R]
>
> Pleo at the beginning… three kids rejected me Pleo in six months. [F1_FG]

Key Topic 2: Interactive practice

- Rewarding responsiveness vs difficulties to interact smoothly
- Prominence of substantial contact
- Symbolic play

The respondents report successful interaction especially when Pleo reacts ostensibly and contingently to children bids.

> [*When is Pleo especially appealing?*] When it seems to respond to the environment stimulus for example if a kid calls it up and Pleo turns to him, or when they caress it and Pleo gets happy. The fact is that kids can see if it is happy for the way it moves the tail, adding the sense of interaction [S_R]
>
> [*Rainbow Room / M_4*]When we were ready to leave, he said hello. At that moment Nihao moved, so the kid cried so happy: "Look! It is waving to me, it is moving the paw!" [S_FN]
>
> From all things that Pleo does, I think, so far, the most attractive to kids is to pull its tail and make it get mad. [M_FN]
>
> (*Rainbow Room / F_9)* He wanted to learn correctly the whole process to make it eat, play and see if there are more tricks (like make it sleep). [S_FN]

On the other hand, some cases of a certain failure in joint action with Pleo and some difficulties to coordinate the interactions are reported.

> I have observed kids under 7/8 years don't respect Pleo's *tempo*. The robot works with its program and the child in a particular moment doesn't wait the *tempo*. He doesn't wait for the caress that trigger the creature. In addition, "let's eat", they stuffs the leaf into its mouth. The *tempos* are not respected. [M2_FG]

Substantial contact and cuddle

The most successful behaviors, when children seem to enjoy more the interaction, are substantial contact such as hugging, cuddling Pleo to make it sleep, petting and caressing it, and when Pleo seems to snuggle against the children body:

> [*What Pleo's behavior children like most?]* Getting asleep, getting mad and eating; maybe from these three behaviors I'd highlight as the most successful when Pleo sleeps down, and when you make it eat the green leaf fooling it with the sugar cane [M_R]

> Moreover, when kids have it in their arms and it moves in a loving and affectionate way squeezing to the kid's body. [S_R]

> The favorite natural behavior is how it snuggles when you hold it as a baby. The way it wants food also attracts a lot. [V_R]

> *(Oncology / F_5 and F_4)* The girls have played today putting the fingers in its mouth; M. thought it would hurt but M. showed her that nothing happened. M., as always, laughed every time someone imitates the dinosaur's noises, Me. was really happy putting the fingers inside the mouth; the two girls have kissed the Pleos because the fathers have asked them to do so. [M_FN]

> The most common behavior is kids hugging it, putting it on their chest and petting it as if they were puppies. Also they kiss it very often. [M_R]

> (*Rainbow Room / F_9*) She was so happy, moving the hands up quickly, with more intimate types of interaction (when the *dino* squeezes its head with her head and it stayed quiet staring at her). Then she showed to other kids how to play with it… [S_FN]

> Kids lay with Pleo in their hug and they "sleep" together. [S_R 3]

> He emphasized and expressed gratitude to the affection movements the doll showed him.
> [M2_FG]

- Boys have this interrelation with it, although it's just caress it ... There are a lot of girls who sleep it. [M1_FG]
- They love this. [F2_FG]
- They love this I don't mind if they follow the *tempos*. [M1_FG]

- It always orients to the face. They put here. It always searchs the person's face [F2_FG]
- Yes, yes. [F1_FG]
- But with the eyes closed, it moves… It opens the eyes to make sure that continues there… [F2_FG]

Pretend play

(*Oncology / F_4*) Once the nurse is gone, Leonard plays the doctor with Pleo, imitating the nurse with the syringe. He told me he has to give it the medication to cure it. First, he only pretend he gives it at the mouth, but then says that he has to give it injections to get well, and pretends to inject everywhere […] then is him who invents, and when Pleo makes noises he says it is hungry or sleepy, and proceeds to fulfill its "needs". [G_FN]

Key Topic 3: Attachment

- Children personalize and individualize Pleos
- Children miss Pleo
- Children cannot wait to see Pleo again
- Pleos are expected, solicited and searched
- Children feel sorry for the separation and difficult farewells
- Interaction skills acquisition through experience

Individualization and personalization

Many children and families want to know which Pleo is presented, or request for one particular Pleo.

…and children ask for the name of a particular Pleo, or ask for the name of the Pleos you brought that day. [M_R]

Moreover, many kids from the eighth floor have a dog or cat at home and at some time there make a replacement. There are kids that call Pleo like their dog, if they think about the *other*. [M1_FG]

(*Oncology / F_3*) A. asks me if it is Tango… [G_FN]

(*Oncology / F_3*) A. is with her mother and both were delighted to see the dinosaurs. They told me that they had already met the three males. [G_FN]

Sometimes are the practitioners who highlight the differences between Pleos, attributing to them specific personality traits and behavior patterns:

It is better that Meg remains upstairs because she is more affectionate. She is lovely… There was a case of a child who couldn't move his arm and I put her on him and Meg was moving up the shirt. At the end he couldn't move, 7 years old. She is so nice and if she sees that an arm *doesn't work* she goes to find this arm. [M1_FG]

Soliciting Pleo, searching for Pleo

Different informers reported situations in which children asked when they would be back, when they could see Pleo again. Some families explained to them that children had been asking for the Pleos or even that they had gone to search the Pleos around the hospital.

As soon as they saw Pleo they remembered they had seen it before and most of them had asked to see it again, even some child had looked for it. [M_R]

Some children ask when we will be back again. [M_R]

Someday I flew to them because they told me: "You have to bring it back to me" and I try to bring it to them. [M1_FG]

At the eighth floor, [*oncology*] they told me sometimes: "He/she is waiting". [M1_FG]

Sometimes when a child has to say goodbye to Pleo because he has to leave –for a procedure, an exploration- they come back as soon as possible to play with the Pleo again.

It's been about three quarters of an hour and A. left because he had to get some kind of treatment. They said good bye until tomorrow, but after a while they was back at the game room because the kid asked his father to come back to play with the dinosaur again. [M_FN]

Children who came back to the hospital and had seen Pleo previously looked for it, and even once a volunteer told us that one child left but asked for Pleo. In fact, once, a mother asked directly to the volunteer's office to find out where we were to come and see us, because her daughter was eager to see the Pleo again [V_R]

In fact, there are kids that are one Monday in the *Rainbow Room* because they will have an intervention and at the next visit if it it's on Monday I say: "If you come another day and it's a

Monday I will show it to you". They come to check how it is doing, if it has grown up. They think it grows in size, but I explain that they don’t. They come to see how it is doing, to say hello and to spend some time with it. [F3_FG]

Glad to see Pleo again

(*Oncology / F_5*) The girl is with her auntie and her grandparents and she is engaged making a puzzle. As soon as I came in the auntie says: “Oh, how good, they bring the dinosaurs!” and the girl is happy and she put the puzzle aside to play with the dinosaurs. [G_FN]

(*Oncology / F_5*) He told me they will buy him one and that they had chosen the name. I ask for the name and they tell me “Nihao”, and I say that there is already a Nihao in the hospital, and I ask if he know it. He tell me that he knows it and that that is the reason why he wants to give that name to it. [G_FN]

Sorry for separation

There are also children who don’t want to leave Pleo and ask if they will see it again and when. [S_R]

[*I wouldn't*] Leave Pleo a lot of time to a child who is very depressed, because then you have to take it, and I say this without knowing if this will be the effect of taking it, but I think maybe it could be worse. [M_R]

(At oncology ward) ... he said: "Claudia princess, let’s take a snack and let her to take Tango to see the other children?”, and Claudia said: "yes, yes, but it doesn't want to leave! I put everything on it to make it leave and it throw it" The girl put onto Pleo food, the stone and the mint and of course, just when it started to move a little all the stuff fell on the bed. Finally we said goodbye and we agree to see again another day. [M_FN]

(*External consultancies*) When he had to go, he took the initiative and hugged and kissed Charly to say goodbye. [S_FN]

(*Rainbow Room*) The girl had the dinosaur in their hug completely calmed. She was looking it and smiling often. I try to touch her back twice. When the doctor called her she didn’t want to leave it and started to murmur again. [S_FN]

(*Rainbow Room*) The 1.5 years old boy was more interested in the Pleo’s *stone* than in Pleo itself. And he cried a lot when he had to go and leave the stone. [S_FN]

> The big boy with some cognitive impairment, has shown to be much focused on Pleo. Because he didn't want to go, I accompanied them (he and his mother) to the elevator and I waited for them to leave. [V_FN]

Memories, shared story, getting skilled together

Children learn and practice social and interactive skills with Pleo:

> [*Do they approach, spontaneously?*] Some do, but almost always when they approach without asking them is because they have played another day so they know it's a thing they may do. [M_R]
>
> They also ask you to give them something to eat if you forget to bring the leaves. Another thing they do is repeat things they already know to do with Pleo: making it sleep, caressing it, feeding it, trying to play with the stone.... [M_R]
>
> … children who were shy at the first and didn't interact much, the next time they take more profit. I found a girl at the consultations who told me she had seen us the other day, but she didn't approach us. Besides, it was a boy, J., who had seen us and rejected the idea to play, while next day at the CyberAula showed more interest. [S_R]
>
> In these cases of reunion (once or more times), child's attitude is more confident from the beginning and they take it quickly or ask to give it food or play with the string and stone: [V_R]
>
> (Oncology / F_3) I am surprised that both the mother and the child remember how to feed the Pleos and what the leaves are for. [G_FN]

5.5.1.2. Collective Gaming with Pleos

Key Topic 4: Inventing stories

- Attributing Pleo *powers*, intent, desires
- Creating narratives to explain Pleo behaviors
- Symbolic play and dramatizations of daily day situations
- Playing together: everyone can join and contribute

Respondents reported naturally the fantasy stories they create with children during play. Configuring and reconfiguring dynamically the social net of participants (e.g. a nurse entering the room, a grandma startling at Pleo roar) that collaborate to enrich an imagined world of Pleo's possibilities and stories.

> In the meanwhile we caught the parents' attention -they were in the rest room- (especially because A.'s father keeps repeating "is amazing!" and also interacts with me and with the child), and then formed a circle around us, with a nurse who also curious approached to see what happened. [M_FN]

> (*Oncology / F_5*) When the mother came she asked her if she could show Charlie to her roommate, C., and the mother answered that she had to ask Charlie; she approached to its ear and said: "She says yes!" We laughed with the kid, she was very energetic today. [M_FN]

> (*Oncology / F_3 and F_7*) In the corridor I find N. (3) with her mother. Then appears another mother and calls her daughter A. (approximately 7 years old) to get out of the room. We were at the corridor and I teach them how to play with the Pleos. When I explain the different types of food they have and that they prefer the sugar cane, A. tells me she really likes macaroni but that they oblige her to eat vegetables as well, because you have to eat everything. [G_FN]

> (*Oncology / F_5*) Grandparents are amazed by the robots and everything it does they comment it aloud ("Oh, it raises the head!" - "Oh, it moves the tail" - "Oh, it has made a noise!"). [G_FN]

Many respondents reported relatives and staff taking advantage of Pleos' presence to create a nice playful situation and even to build a story with other purposes like exemplarizing some situation of child's live (i.e. a clinical procedure).

> (Oncology) A. keep asking his mother to take it and to feed it as he does, and the mother replied: "maybe it doesn't eat because you don't eat, if it sees you eating maybe then it will eat too; do you want to try?". The kid said yes, and he ate a sandwich (I don't know if he was hungry, but he wanted to see if Tango also ate). [M_FN]

Frequently, the group engaged in make belief and pretend game inventing narratives that make sense to Pleo's autonomous movements and sounds with funny interpretations and guesses. Ordinary incidents with Pleo -such as running off batteries-, elicit as well imaginative explanations as an attempt to integrate maintenance into the game as well.

> Suddenly Charlie's battery drained out, and with the parents we explained that it had fallen asleep. [M_FN]

They explore as well new ways to introduce other play elements, like dolls to build a symbolic play with Pleo (e.g. riding a Barbie on Pleo) and attributing Pleo roles, traits and intentions.

The rest of the section the key topics are organized according to the subject taking part in the game: parents and relatives, volunteers and nurses and other clinical staff.

Key Topic 5: Parents and relatives

- *Helping* children to play with Pleo
- Enriching the play situation
- Enjoying themselves
- Parents soliciting/seeking Pleo

The respondents reported that parents usually engage in playing with Pleo when they see their children interested, to enhance and share with them the experience, derived by their role of care-givers facilitating, encouraging, praising.

> (*Oncology / M_16 and M_7*) Then M.'s mother came and the son asks her to make Charlie sleep, because I told him he was a specialist in dinosaurs and he told me: "yes, but there's something I can't do" we have asked what was it and he answered "make it sleep". [M_FN]

Wonder, interest, curiosity and playfulness

Sometimes, though, parent's interaction towards Pleo is not related to children's needs but to their own interests, curiosity or enjoyment.

> (*Oncology*) There was a moment when the girl ignored Nola and I saw her father couldn't stop taking it and looking it everywhere, afterwards, if someone was looking at him he released Nola on the table, but after a while he took it again while his daughter was playing with other stuff. [M_FN]

And it's precisely because it is a baby, I think it attracts the adults more. [F2_FG]

Sometimes relatives have heard about the Pleos and try to find them. The popularity of Pleos in the hospital community and the speed the experience had spread out is something that are highlighted in all the reports. Certain *myths* about the wonders and capabilities of the little dinosaurs were repeated and commented.

(*CyberAula*) J. (9) and A. (7) came accompanied by the father of one of them, and they told me they had come because the mother, who is the one that had come back to return the toys, told them that there was a very cool robot downstairs. [S_FN]

Taking pictures and videos is a very frequent behavior. Respondents reported as well that they send the pictures to relatives and friends and that they were eager to share the moment of amusement and wonder with them.

The boy was all the time telling his father things like "father, look how I take it, dad look," he gave it to me too but immediately he wanted it back. When we had been playing for fifteen minutes the father decided to start taking pictures and then started to video record too and he told me that he wanted the boy's mother saw how amused her son was... he received a phone call from someone who asked for the kid and he said: "You should see him, he is with a dinosaur that can do everything, is amazing". [M_FN]

A.'s mother and the lady started taking pictures while the child played with Lionel [M_FN]

Parents also were very interested and happy: a lot of them have taken pictures to theirs sons with Pleo. [V_FN]

(*Oncology / M_1,5*) But he said goodbye with kisses and all the time called "daddy", and the mother recorded him and made pictures so N. could show his father who had met this afternoon. [M_FN]

In this case, the beneficial effect of playing with Pleo seems to extend beyond the hospital walls and reach the relatives that are not there but are concerned or worried –maybe even more than presents-, to reassure them, to let them know that they are having a good time and that the child is alright.

(*Oncology / M_3*) The mother takes photos of A. with the robot and send them via WhatsApp to her friends, then she asks me to take some pictures of them with Pleo, because her friends wanted to see her as well! [G_FN]

And upstairs it’s important the reaction of parents, what we said before, everybody takes pictures. Especially the first day, the first time it is there they rushed to send pictures to the sister to show he was happy, that he was having a great time. Of course also relieves the whole family, not only the presents but everyone. [M1_FG]

Appreciation

She told me the kid wanted a pet, and that because of his illness this will not be possible, she thinks that might be a good option, and no one said he couldn't have something like this, perhaps it would be good to have one because, "seems real". [M_FN]

Encouraging, Facilitating, Regulating play

(*Oncology*) In the room there was M., today he wasn’t not very lively but the mother wanted him to play and at the end they interacted the three of them, and he showed some interest, even we managed to make him hold it during a while (I think this kid has pain). [M_FN]

(*Rainbow Room*) When he squeezed it harder the parents always intervene to prevent him of doing so, giving instructions of how to treat the dinosaurs. [S_FN]

(*Oncology / F_17*)… she is lying in bed ant she seems not feeling well. Her parents make her company. I don’t dare to put the dinosaur on the bed. The father clears off the table and tells me to put it on there and push the table besides the bed. M. straightens up and sits on bed to better reach. I remain there for half an hour. The parents seem so implicated, they make it sleep a lot of times and give it food. The father records and makes pictures of M. with Pleo, they seem to have a good time together. [G_FN]

I meet two girls about 5 years old who are afraid of Charly. One father insists a lot to make his child touch it, he approach and shows how to do it, and tell that’s it is inoffensive. [S_FN]

Requesting

Respondents noted that many parents tried to find the volunteers with Pleo to request them for their children.

(Oncology) and Claudia's parents (especially the father) asked me if I could go to the girl’s room who could not get out. [M_FN]

(*Oncology*) Some mothers urged me to enter into the rooms because there were some kids who couldn't go downstairs to join the activities and they were laying and resting because of the medication and the chemotherapy. [RO_FN]

(*Oncology*) Then a mother come in, was looking for me, and asked me to borrow a Pleo to show it to his son, who is at the bedroom, and she said she knew how to use it. I gave her the sugar cane and Pleo's toy and she left very grateful. [G_FN]

(*Oncology*) Just then, another mother comes and asks me if I could go to her son's bedroom and bring it to him. [G_FN]

Key Topic 6: Volunteers

- *Helping* children to play with Pleo
- Enriching the play situation
- Enjoying themselves
- Soliciting/seeking Pleo
- Attachment with Pleo

Enjoying

Today the volunteer named C. started taking pictures of Lionel with the phone's camera. [M_FN]

Enriching

Now I turn it on when I'm there so they see how it wakes up, I explain everything it does. I tell them it even has "rolls of fat". It's funny, it's human. I say: "If I had to be with him, I wouldn't do anything else. I couldn't pay attention of anyone else". I look and thereafter it passes from hand to hand [F2_FG]

I explained a little what Pleo is about. There was a lady who held it in her arms and it fell asleep. After a while she said: "It's already sleeping, put it at the bed again", I take it and I put it. It only was that family, others already have gone. And it starts moving. I say: "Ah, ah, no, the battery still works", i give it back. It fell asleep again. It didn't want to stay on its bed, it wanted to stay in the arms. They love it. [F2FG]

I say: "We have to treat it as we would like to be treated because the way we treat it will mark its character as an adult". They stared at me. And above all, I say, it grows like us but no like a

Tamagochi who in a month passes for all the life stages. They ask: "But it grows up?" I answer: "No, no. Physically it remains the same but the behavior…" [F2_FG]

(Oncology / M_16 and M_7) M. asked me to trick it and finally Nola and Charlie both ended with a mint leaf in the mouth; four minutes later, the dinosaurs still keep the mint leaf in the mouth (they "talk" to each other with the mouth full!) and we decided to make a bet about who will be the first to leave the leaf. M. bet for Nola and O. For Charlie; M. won because he cheated, we need to put the sugar cane under the mouth again to make it open it. Mohamed asked me to give it to Charlie and he has put it over him and was able to fool it. [M_FN]

(*Oncology*) Both have made Charlie sleep and have changed its diet! If you didn't know, Charlie likes peas (he hold it in the mouth like it was a leaf), he likes pizza too, but not much because it drops it soon, and the same about macaroni with tomato. [M_FN]

(Oncology / F_3) A. also remembers how to fool Pleo, and he explains it to me: first he puts sugar cane on the chin, and when it opens the mouth he gives him the "real" leaf or makes it play. The mother tells me that it is so funny when he plays and treats it as if it was a dog. [G_FN]

Key Topic 7: Nurses and clinical staff

- *Taking advantage* of immersion in the play
- Regulating Pleo's play
- Helping and contributing to the play situation
- Enjoying themselves
- Soliciting/seeking Pleo

The interest in Pleo by the professional staff ranged from curiosity to cheerful approach and active play.

...they are delighted to see them [*the Pleos*] in action. We stay there for about 8 minutes and they really seem to like them and to find them useful and the project interesting. [G_FN]

Many entries in the diaries refer to the experience propagating quickly around the hospital and volunteers and clinical staff often addressed the team to know more about the robots and the service and to experience the interaction with robot.

....quite often the nurses stopped us as well and asked what we were doing and how cute Nihao was... [M_FN]

The nurses addressed me and showed up to be very positive about us wondering around and [they told me] that a lot of parents and children talked about the "dinos". Some nurses had changed shifts and had not seen the dinosaurs yet so they were called to come and to have a look. [R_FN]

Remarks reported in the diaries are always appreciative. The lack of criticism can be explained according to a general positive disposition to respect and support other's work and initiatives and to be receptive to innovation that is one of the hospital dominant cultural traits. Most probably negative, skeptical or critical views about the robot –if any- would barely reach spontaneously the team for the same reasons.

(Oncology / F_5) The girl wanted to ask a nurse for plaster for Nihao's tail and we healed it, although he did not realized because by then he was K.O. After fixing the dinosaur's tail we talked a little and the girls asked me if I would come tomorrow. [M_FN]

(Oncology / F_4) *He mistreats Pleo, forces it to eat and take it brusquely, but seems he has a good time. After a while a nurse enters and gives him the medicine with a syringe. The nurse* made positive remarks about the robot, she says that it is a big success and that the kids really love it. [G_FN]

5.5.1.3. Serious Pleo

Although initially restricted to video games, the expression *serious games* defines a software-based device that has for a primary purpose other than pure entertainment, this is to say that combines a *serious* dimension with a *game* dimension. The tittle of this section account for the serious purpose of playing with Pleo, with an emphasis on the efficacy or usefulness of Pleo as a therapeutic resource, based on its potential in gaming dimension.

Key Topic 8: Health related effects

- Immediate distraction of children and families
- Company
- Anxiety relief and cheer up effect in children and families
- Amazing effect with children with special needs
- Changes in the unit climate
- Facilitating communications: practitioners/families, parents/children, between children
- Helping to break isolation and to express emotions both children and relatives

Children

Distract and relieve concern, anxiety and pain. The appeal of Pleo's behaviors and the absorption of children play creates a suspension of the negative emotions of fear, concerns and even pain.

> (*Oncology / F_14)* I know I repeat myself but really changed the expression of his face, they forget the pain for a while, I believe more than ever that the circuits of pleasure and pain are the same. [M_FN]

> (*Oncology / F_5)* ...and she started crying and I managed to make her laugh fooling Charlie, pretending we were giving her food and cramming the green leaf when it opened his mouth; children really liked her and it was effective to calm and to distract them. [M_FN]

> (Oncology / F_17) Then I said goodbye and they thanked me for the visit. When I was living a nurse told me that certainly I had distracted her, because she hadn't a good day, M., and she also thanked me. [G_FN]

> For example, the dinosaur is very useful in these moments of anxiety when they take it, pet it, all that [F2_FG]

> It calms a lot the uneasiness. I mean it is so… it relaxes. The fact of petting it, while they are petting it… "Look, now we are going to feed it". Calms this anxiety they feel. [F3_FG]

In fact, not this Monday, last week, I accompanied one child with the Pleo I just needed to put the surgeon's clothes and enter at the same operating room because the kid was so attached. In addition, one 8 years old kid, if I'm not wrong. He got a diazepam because it was the third time they tried to operate him but it wasn't possible because of the anxiety attacks. We calmed him with Pleo. But, then arrives the assistant to take him. He didn't want to go. We went with Pleo. Until he fell asleep he was with Pleo petting it. [F3_FG]

(Oncology / F_14) The girl had a pale face white as snow, but I approached Lionel to her and I put it on the bed besides her trunk and I explained to her that the poor thing was quite sick and that only wanted to sleep and be caressed, that was good for the girl, I explained how it was to make it sleep and she wanted to do it herself. [M_FN]

Children with special needs

(External consultancies) A boy with cerebral palsy was delighted and excited with the Pleo, and he pet it a little. That was very good in children with these problems. [V_FN]

(*External consultancies*) A girl with cerebral paralysis (older than the one yesterday), liked it a lot and petted it. Also, with her mother's help, the girl introduced her teddy bear to Pleo. [V_FN]

Then another I put it on a kid with cerebral palsy who was in the chair, 16-17 years old. I put it in his belly and he laughed because he felt Pleo's movement and we talked to him and he laughed. Well, we didn't know exactly why but we guessed it was because Pleo moved. And these things touch you. [F3_FG]

(External consultancies) A girl with Down syndrome also enjoyed it so much and interacted a lot of time with it. [V_FN]

Many respondents reported successful interactions with children with ASD, TDH and other cognitive and development disorders. It seemed like Pleo is capable to attire the attention of children with different disorders and in general to enhance their responsiveness to social stimuli more easily than other toys, games or activities.

There are multiple experiences you see every day. For example, there are hyperactive children and parents that are so as well, and sometimes with Pleo is what we have, after a relaxing time they are all paying attention to Pleo. You can see that every day, different reactions. [F1_FG]

And the mother, you saw that mother. Look, I think about it and… How he treated the puppet, she said: "he doesn't interact with anyone or anything" and at the beginning he lied down very reluctant. We let it there and he was approaching… Well, it was a situation… [F3_FG]

- With autistic children it's amazing. [F3_FG]
- It's something incredible. [M1_FG]
- Not only with the first case, with kids who has been here and with TDH too. You see them… [F3_FG]

Upstairs it does them very good as therapy as well; petting it, moving it… it's therapeutic. I've seen kids who couldn't move and Pleo caresses them, it looks for them. [M1_FG]

(*External consultancies*) A girl with a mobility impairment in her hand because of an operation or something similar, and though at the beginning the mother had to motivate her a little, petting Pleo was a motivation to use and move the hand. [V_FN]

Families in the pre-surgery waiting room

One of the first units Pleo was brought by the Child Life was in the pre-surgery waiting room, named Rainbow Room. In fact, Pleos initially were assigned to the volunteers working in this the pre-surgery waiting room and in the oncological ward. We can say that Pleo's *debut* was in this room. The children that has to pass a surgery that requires further hospitalization and their family wait in this room. They are considered especial admissions that require psychological support and follow up and are attended closely by the Child Life.

[…] but parents are a very important factor in this place, in the Rainbow Room, because they are distressed their kids passing a surgery, entering the operation room. […] Then the anxiety… The Pleos are very good for them, really good. It brings relief… [F3_FG]

The accompanying person is there and is super distressed. Then Pleo allows to release all this attention, this love. Of course they could do it to their son, who is next to them. But the kid is the reason why they are so upset; they are here for he/she. So Pleo is a way… is like they were paying attention at their son but this is a parenthesis. [F2_FG]

Where I am [*Rainbow Room*] it calms a lot. [M2_ FG]

One of the more referred effects of Pleo is to calm down relatives' anxiety, to distract them, to let them focus on something else apart from their concern and fears.

It allows them to disconnect. I've seen people very distressed and hold Pleo and change his face. In fact once was a man who was sleeping, who lied down *that way* with the Pleo *here*. Sure, he was very relaxed. [F2_FG]

It's true it relaxes a lot. All the family. It's balsamic. It's like people entered an almost sleeping state [F2_FG]

As a therapy I haven't seen anything more effective than Pleo, to disconnect, in a manner of speaking, because you never disconnect. But it works to release that anxiety. There are always peaks in that wait. They may be waiting five hours going through different peaks. At high tension's moments Pleo allows… it's an escape valve. When they play domino or coloring it helps, but it doesn't make the effect that makes Pleo. [F2_FG]

[...] I saw the face of a woman who was completely collapsed [...] So, I gave her it and was taking it ... [F2_FG]

I summarize because they are several similar cases. The mother, I've also founded with men but basically the mother, is crying, she is so distressed. The simply fact, I sit next to her, "Look mummy", and put it and it's the simple fact of taking it, to start petting it and holding it like this that it's therapeutic. The therapy starts in that moment, then after a while this mother will laugh, talk. And the anguish is gone. It will come again when the attendant with the litter arrive but at least we have broken this… that we didn't know how it would have end. Then we break it and the time she is there at least she spend a pretty quiet time. And I've seen it many times, many many times with the mothers. [F2_FG]

Respondents reported that sometime parents need more attention than children and Pleo is a good resource to attire their attention and to distract.

Sometimes parents need it more than kids in a particular moment. [M1_FG]

The experience I have is more related with the adults than with the kids. [F2_FG]

If the kids are about 6 months, is more for the parents. [M1_FG]

Reported a change in the general climate, like a relief of the tension.

When you have introduced the dinosaur the circumstances change. The world changes. Parents usually are more receptive. [M1_FG]

Another recurrent reference of respondents is the way Pleo facilitates the flow of communication with volunteers, breaking the isolation.

It is a material object that facilitates me a personal relationship. [M2_FG]

I think I don't have to interact with it at all. It is the kid and their parents. Any case, I have to take advantage to speak with the parents about… If they are grown up kids we speak about studies, whatever while they are playing. [M1_FG]

> But so many times people suffer their anguish in a corner. Then, what I do is to try to break this isolation. Pleo helps me a lot in this task. [F2_FG]

> Besides, it encourages a lot the interaction between families. A lot. Sometimes it happens that a family is more open, more extrovert, and explain their stuff and draws everyone. [F2_FG]

Children communication and children comradeship

> [*In daily hospital*] Now Pleo is very useful to make kids going out boxes to a common area to play, because we place the Pleos there. We do so because nursery asked that: "Anyone who are able has to go out". [M2_FG]

> But the Pleo, even for the kids themselves they interact more with each other. Because sometimes when you say: "Between three kids", you put it in the middle and one gives it food, the other… There are kids who are really isolated and this way they interact. [F3_FG]

> I haven't seen individualism, when they see Pleo it disappears. They are playing with something, then they see Pleo and start playing two or three of them. [F1_FG]

Key Topic 9: Professional compatibility

- Pleo is very well accepted and regarded with interest
- Nurses smoothly regulate Pleo-based activities
- Nurses take advantage of Pleo presence for caring tasks
- Nurses solicit Pleo to attend children and mediate parents and children requests

The respondents discussed experiences and situations that we consider indicators of the first stages of appropriation (i.e. taking something that belongs to others and making it one's own).The informers reported nurses accepting volunteers Pleo, showing interest and even delight, regulating the use in the units, and even proactive solicitation of Pleo as a useful resource.

Acceptance, Interest

> At the beginning, those first days I thought: "I don't know what I will do with this", it will difficult me to dedicate to people because it demands a lot of attention when it starts to waking up that I say: "Well, if I'm attending it I can't be attending people". And no, by no means. I found this system and I'm with it and with people and people are delighted. [F2_FG]

> Well, it is useful for you because it’s clear that you are still doing it. [F3_FG]

> In my case is a resource that at the beginning I used more, now no so much. [M2_FG]

> Well, well, people like it. I always go with the basket and if I meet someone: “You go with it again! And everybody put their hand inside or if I hold it in my arms, they touch it. [F3_FG]

All reports account for a respectful and positive attitude from but without direct involvement from nurses what their attitude is not perceived as a lack of interest or skepticism but a distribution of tasks according to the respective roles. Nurses are regarded by researchers as being always very busy and committed to their tasks, focused on their own professional goals. Compared to nurses’ role other services are seen as complementary and are expected to be delivered by side service autonomously but always under their supervision and regulation. There are a differentiation between the core health practices and the complementary services to improve children experience.

This opposition between work and other services seems to be central to regulate the complex network of actors involved in children care-giving. Work in this entry has a strong meaning related to the responsibility and accountability of children’s health that is supported by nursing and with respect to which the services that are subsidiary.

> (Oncology) At the beginning H. had to leave because they had to plug the line to the power, but the kid refused, so they improvised something with the game's room plugs. [M_FN]

Regulation

According to their respective role, the different actors facilitate/allow the access to spaces (e.g. children rooms, closets with toys and other material), explain and supervise the observation of safety procedures (e.g. sanitization) and other rules (e.g. routines scheduling).

> As I arrived I asked the nurses how I should sanitize the Pleos and what rooms I may come in. They explain to me and provide me with every facility to enter the rooms; they just warn me to rubber the Pleo with a disinfectant and a gauze pad and to wash my hands. [G_FN]

Taking advantage

One significant and insightful finding is the way nurses take advantage of Pleo’s potential to distract children to undertake unnoticeably the care routines. There is a significant amount of entries in the field notes that point out this situation where nurses seem to wisely and smoothly take advantage of the engaging playful situation.

> Surprisingly one of the kids had to be attended by the nurse to change a catheter and to fix some stuff in his waist. The kid was paying attention to Pleo petting it and getting it to sleep upon his breast. During the whole procedure the child did not noticed the nurses' manipulations. He took care of it, stroked it and looked after just as if it was a pet. [R_FN]

> There are always one or two [*nurses*], but it changes. You found no rejection. There is never rejection. They see that it doesn't go bad. Sometimes they take advantage while I am there and they put them the injection because he/she was playing with Pleo. [M1_FG]

Requesting

A prominent sub-theme identified is nurses taking the initiative to request the presence of the Pleos to satisfy children or family requesT. In these situations the hospital staff acts not just as a mediator or messenger between children/relatives and the service but soliciting their presence what implies not only the resource –Pleo- acceptances and allowance but the attribution of a valuable resource in the task of caring (i.e. ameliorate the child mood or to smooth a procedure). In this sense is very significant the remark of M. in the report:

> ... as I said before, often they [*nurses*] play the role of a messenger between us and the children that could not leave their rooms (I have the feeling that even they do so by their own). [M_FN]

We consider that requesting a resource implies professional validation and confidence, and an implicit assumption of its effectiveness on therapy or wellbeing related outcomes.

Due to the importance we confer to nurses requesting Pleo in the process of appropriation we reported here all the occurrences registered by the researchers' diaries.

> ...and a nurse told me that we might also enter the rooms of children that couldn't leave the room [M_FN]

> The nurses gave me the sanitizer and told me that I may go into A.'s room [G_FN]

> When we arrived a nurse in the corridor told me that A. was waiting for me, seems like there was a lot of expectation in the room to see the dinosaurs [M_FN]

> As I entered the ward a nurse asked me if I could go to a room where was a child who had passed a surgery in the leg and could not move and who had asked for the dinosaurs [M_FN]

> When I was there a nurse came in and told me that there is A. that waits for me at his room because he cannot leave the room [M_FN]

A nurse came in and asked me if I could enter to see M. that was asking for me [M_FN]

...and then the volunteer told me that a nurse had called her to tell that there was a girl in the 5th floor that was really disheartened and to ask if they could send to her someone or do something... she gave me the girl's name and the number of her room and I headed there [M_FN]

When I go to critical care very often they ask for it. Now I go there regularly. The nurses come to bring me there, -they knew I was at the eighth floor-, because a kid needed it. [M1_FG]

Then I bring it some days because they want it, particularly some kids. The nurses who wanted it most are from critical care because the clowns don't go there, no one goes there. Then, for sure there are people who need it. Parents or… [M1_FG]

(*Oncology*) When I had been there for 15 minutes, Cristina appeared and told me if I could go back to the room because it was a kid who was waiting me. [M_FN]

(*Oncology / F_17*) One volunteer asks me to enter in a girl's room who is really disheartened. [G_FN]

Key Topic 10: Maintenance issues

- Short autonomy: batteries dried out
- Quick deterioration
- Need to sanitize

Many issues of malfunctioning and deterioration were reported by researchers and volunteers, like the lack of robustness to be played by children in group, sudden blockage of joints mainly the neck or a leg –sometimes reversible sometimes permanent-, the skin peel off at the back due to children petting and touching and cuts in the tail. The deterioration is sometimes very salient and the practitioners try to avoid giving the damaged Pleos to children. Sometimes adults treat Pleo's cuts and bruises with remedies quite handy in the context of the hospital: bandages, sticking plasters. Healing Pleo and Pleo's *impairments* and *injuries* play often a part in the narratives during interaction and pretend play.

Also recurrent was the reference to the limited autonomy of the robot because of the batteries that made necessary to bring always a charged extra battery to not interrupt abruptly an episode of interaction.

Respondents raised concerns about the sanitization of Pleos with a special emphasis on Pleos visiting the oncology ward. This issue was discussed in several follow-up meetings with the in field-team, showing out both the impression of fragility of children in this ward and the commitment of the researchers with the rules of the hospital and their willingness not to do anything disruptive or inconvenient related to the care routines. Finally the sanitization and rules to access to rooms and children was regulated by the ward nurses very naturally.

Table 5-10 Questions addressed to researchers

Topics	**items**
Children	Pleo's behaviors that are nice (to all or per age groups etc)
	Pleo's behaviors that annoy / irritate. To whom? Why? Situations and contexts.
	Age range observed (minimum and maximum) and more frequent ages.
	Have you observed behavior differences between boys and girls?
	Children with disorders or observable limitations (mobility deficits, intellectual). Specific behaviors with Pleo? Some kind of patient who could benefit most in particular?
	Conduct with physical contact with Pleo, rare and common behaviors observed.
	Approach to Pleo, if Pleo is in the ground do they approach? Are there children who do not play in the whole episode? Situations and contexts.
	List of rejection or fear behaviors. Location (the child was in bed, the adults cheered etc.)
	Behaviors of abusing Pleo (such as animal Pleo) and misuse (Pleo as a fragile device)
Adults	Attitude of parents and families. More frequent comments. Direct interaction with Pleo observed with adults. Behaviors facilitating interaction and motivation of children.
	Attitude of volunteers.
	Attitude and behavior of nurses towards/with Pleo as a support activity. Compatibility with their job? Complementarity, see it as a resource that can be useful? Any comments or suggestions appreciative? Moments or situations where it is appropriate?
Services / spaces / situations	Of all the situations observed which ones do you think the Pleo fit most and why? Which situations do you find entail more difficulties or are less appropriate?
	According to your experience, do you think it would be interesting to propose services in outpatient surgery (pre-operative time and post operation time before discharge); blood tests, emergencies, other tests (X-rays), other treatments (radiotherapy, chemotherapy)?
Other	Major limitations of Pleo in different situations
	Problems to solve (technical or otherwise). Situations to avoid.
	Do you discard some kind of child / or situation in the intervention?
	What could make Pleo more engaging for children?
	Ideal situation in which the support of Pleo could be maximally effective.
	Do you think that a long-term company -say over a week- could maintain children interest and deploy the role of a pet? Under what conditions?
	Regarding other resources for hospitalized children quality of life (hospital clowns, workshops, therapy dogs) what is the added value of the Pleo based intervention?

5.5.2. Lasting Relationship

Initial encounters

The first encounters between D. and Pleo took place in the *CyberAula*. D. was always with her siblings and her mom. D. showed to be very appealed by Pleo –the first two encounters were with Nola and the third with Charlie and Lionel- engaging in different activities as feeding, petting affectionately, hugging, and making it sleep. D.'s interactive style was different from her brothers who were more brusque and anxious to obtain active responses from Pleo. D.' play was always mediated by the facilitator and by D.'s mother, that appeared very interested and took part actively playing with the D. and her sister C.. The girls got very excited when the Pleo performed Invitation *to Play*. The activities observed were feeding Pleo, petting, playing together with her sister, and elaborating a more complex pretend game with Pleo becoming a monster threatening to eat some little puppets of D. D. seemed to enjoy the activities and to like Pleo and laughed happily at Pleo's funny sounds. In the third encounter with the two Pleos, the children played to put them in a queue one behind the other The two girls played together, the youngest mimicking her sister and competing with other children to keep the Pleos and play with them, in a lively and exciting collective game -not without some conflicts- in which, again, the mother took part actively.

Programmed activities with Pleo

At the activity *Pleos' farm* D. spent all the time playing with the Pleos. In this case the situation was quite different because of the scenario –Pleo's farm- and the fact that there were 4 Pleos to play with, for the 6 children participants.

At the workshop, D. spent all the time playing with the Pleos, mainly individually, but also coordinated with her sister, with the help of the facilitator. She preferred keeping the Pleo and not sharing it. A significant amount of time was spent with physical contact with Pleos and particular with substantial contact –body to body- with Pleo. According to our model, his liking of substantial contact is an indicator of intimacy and affect that constitute emotional bonding. D. seemed to be very pleased to be in close contact with the Pleo and did not engage in dyadic patterns other than feeding. The 90% of the time D. kept engaged with Pleo. We can conclude that the experience value was at its highest level and no indications of the end of novelty like disenchantment or disengagement were observed.

Owning a Pleo

The family and D. accepted very excited adopting a Pleo. The parents reported that D. was really eager to keep one. The delivery of Pleo coincided with a worsening health condition and D. could not go to pick up her Pleo at Pleo's place but was waiting in her room to *receive* the one her family –father and siblings- was bringing her. In fact, when the family agreed to adopt the Pleo the feeling was that the leave was very close and that the Pleo would be a companion for D. in their last days or few weeks before the discharge from the hospital. This situation have changed when the Pleo was delivered with a consequent an increase in parents' concern and a change in the expectancies of recovering the family *normal* life in a near future, what resulted in disappointment and concern.

The official reception of the Pleo, when the robot was given in temporary adoption, was a very enjoyable situation. D. was in bed seemed really happy. D. and her mother shared the moment with complicity and got tremendously excited because finally they were delivered the one they preferred –Nola- and felt most fortunate. In this case is clear the individualization and personalization and the excitement of D. because the new situation of owning a Pleo. In the same moment G. make Pleo to perform some tricks that were a real success. All presents laughed and seemed very excited by the funny performance that surprise even to G. because she herself was not always able to make Pleo *obey* the commands. We left the family and come back after a short time just to check if everything was alright. In the meanwhile, he mother have tried to repeat the tricks but she had not succeeded. In fact, the family never managed to make Pleo learn a single trick. We consider that this situation was a factor of disappointment and frustration and an obstacle to a real appropriation by the family.

In terms of De Graaf's model (De Graaf et al., 2017) it would be an instance of two factors of non-use. First, a need not satisfied because of the lack of autonomy of parents in expanding Pleo's behavioral repertory defeat the expectation of perform as really owners and trainers and be able to conduct new playful activities to entertain their kids. Secondly, they are forced to rely in others to use effectively the robot, needing to ask for help to expand Pleo's performance.

During this time, the family passed difficult situation because of D. worsening condition due to changes in the medication and because all three siblings passed the flu.

After the second week the parents reported that D. seemed to had lost interest except when she is in bed when she enjoyed to be with Nola and to pet it. Parents complained about the difficulties to stablish contingent sequences of interactions with Pleo and the lack of usability for children that barely detect the subtle changes of the pretended evolution of Pleo, and changing moods. They reported as well that every child interact and relate towards Pleo in different ways (versatility), and that it is a real attraction for other children in the unit that are always hanging around asking for the Pleo (social orientation). Maybe this role of social facilitator was not always appreciated by the family that felt obliged to be polite to share the Pleo with the other children when required.

Both the Child Life and the Head of Innovation remarked in informal conversations that while during the first week D. took the Pleo everywhere, lately they did not see D. carrying the Pleo so frequently and even they asked us if we had recommended to the family to keep the Pleo within the room. In fact, during the hour and a half of the first follow up interview -4th week- D. did not even look at Nola. D. was not feeling well those days and that could have influenced in her loss of interest.

After 5 weeks the family seems to have lost interest in Pleo. The father talked about the competition with a tablet they had been given and that the children were very excited and engaged with it because of the huge potentiality of different games or activities offered. Implicitly, there was making a comparison in which playing with Pleo seemed monotonous and reiterative without new challenges or potentialities to implement. The tablet was to some extend replacing Pleo (*Replaced by other device* in De Graaf's model), offering a better solution to the need of keeping children engaged and entertained. They also reported their concern about Pleo been stolen in a distraction that can account for *(Restrictions and problems* in the model*).*

Finally, parents seemed to lack motivation to sustain a pretend play that children seemed not to enjoy much after a period of time, disengaged from the robot and only committed with the experience to collaborate with us.

5.6. Lessons Learned

This section addresses the opportunities and limitations for longitudinal HRI research in the wild and in particular in pediatric contexts. The findings on interactions and emotions towards Pleo, the relationship with Pleo in the long-run and the reflection on the effectiveness of the Pleo-based intervention are discussed in Chapter 6 *Discussion*.

1. Pediatric settings impose strict limitations on research techniques to protect children wellbeing and privacy, like video recording.
2. One of the difficulties of longitudinal intrasubject design with patient children is to keep participants involved enough time to carry out the different observations and the follow-up. Children's stays in hospitals are becoming shorter and shorter because of the improvement of techniques (e.g. surgeries) and for children wellbeing considerations. A very accurate selection of participants has to be done to ensure a long enough access to participants to complete the study.
3. Consequently, nowadays hospitalization is only indicated in the first phases of recovering from a surgery or other invasive treatments, in case of severity or any other condition that require continuous professional monitoring or procedures that require hospitalization because of their effects on children's condition or by their frequency. In this context, most of hospitalized children feel sick and unable to engage in activities, especially when they are confined to their rooms when resting in bed or with and intravenous treatment. In this late case, they may have a restricted mobility out of their rooms, according to their condition.
4. A pediatric hospital is a very specific context and findings of previous ethnographic studies in children-robot interaction in other contexts -schools or homes-, are hardly applicable. Overall, a pediatric hospital is a *serious* field, a place children attend to be cared and cured. hospitals are relevant and significant institutions in our society are a "domain where the core values and beliefs of a culture come into view" (Van Der Geest & Finkler, 2004) with a transcendent mission –taking care of fragile children- that override any other purpose, interest or activity. Everything going on in the hospital (e.g. research) has to adjust to this main goal with is supported with high commitment by the caring net, and continuously supervised by nurses.
5. In many cases, children's condition is very variable and make very difficult to make plans and to know in advance what they would be able to do even in a few hours advance. The life in the hospital and the resources adapt quickly and flexibly to any

change on children condition, and scheduled activities have to be rearranged, redesigned or cancelled to meet children needs. Many resources as the hospital school, the mobile library, craft workshops, music plays, are delivered at children's rooms or in the shared spaces in the wards. According to their health condition, children are encouraged to get out of their rooms to meet other children and families and to engage in collective activities.

6. Discussion

This chapter covers the discussion of results and findings drawn from the two empirical studies reported in chapters 4 and 5 respectively: the systematic observation of children playing with Pleo in pairs (section 6.1.) and the ethnographic study in the pediatric hospital (sections 6.2., 6.3. and 6.4.).

6.1. Bonding Dynamics Playing with Pleo in Pairs

Overall considerations

During the six trials Pleo performed fully functional and autonomous, and required very little supervision and no external intervention except when eventually Pleo fell asleep. In this cases, the conductor entered the play area and turned Pleo on ostensibly in sight of children who were able to recover Pleo from sleep by themselves in subsequent occurrences, though some of them requested the adults' help or permission to turn Pleo on. Pleo falling asleep was a recurrent event that happened by chance at least once in every trial and arose interesting children's coping behaviors such us speculating and discussing causes and consequences of the sudden shut down, expressing feelings of surprise, frustration, failure or even guilt, and exhibiting diverse actions attempting to make Pleo awake by their own or requesting the conductor's help.

The low number of subjects in our study limits the statistical conclusions that can be drawn, but that limitation also allowed a focus on a finer analysis of each session, which is relevant for a system that puts the emphasis on understanding the *whys* and *hows* of children interacting towards and reasoning about the robotic pet.

We must acknowledge that the data analyzed in this study is only a fairly crude approximation of the elaborate social behaviors that children exhibit when playing with Pleo and that we have been observing during the last seven years in different scenarios and settings (see Tables 4-1 and 4-2).

Between Subjects and Between Dyads' Variability

The first conclusion is that children exhibit very different interactive styles in intensity, variety of activities and actions toward Pleo, and in verbal production. Moreover, in the situation of unstructured play in pairs, the individual behavior is assumed to be affected not only by Pleo's behavior and individual variables (i.e. attitudes, copying styles, perceptions) but also by the dynamics of the triadic situation (i.e. dominance, regulatory actions as turn taking).

From the descriptive analysis of frequencies, we can underline the high variability between subjects related to total activity towards Pleo and also related to the patterns of interaction. *Activity* (total number of behavioral units registered) ranges from 14 (Child_3) to 83 (Child_5) between individuals and from 73 (Dyad_2) to 126 (Dyad_6) between dyads. In sessions lasting about 500 seconds the differences in the amount of interactive behavior deployed is remarkable. The individual intensity (total activity rate) ranges from a minimum of 1,7 behaviors per minute to a maximum of 10. The dyads' intensity variability is somehow compensated by the individual differences intra dyad and ranges from 8,8 to 11,5 behaviors per minute.

As mentioned above, provided the observed situation was free play in pairs the social dynamics between players also influence the overall performance during the session. Two main effects are hypothesized: each child in a dyad tends to mimic or align with the playmate's interactive behavior (either in intensity or modality) or, on the contrary, the children self-organize acting complementarily to each other (e.g. one very active and the other more passive, one exploring the material and the other interacting physically with Pleo).

Engagement and Interest

Although in the study set-up Pleo was able to engage only in a short range of activities and children were expected to quickly understand its limitations, children remained interested and motivated during the short time of interaction (8 minutes scheduled). The dyads spent all the time available playing with and speaking about the robot, except from Dyad_6 that showed signs of boredom, frustration and a general negative -even obstructive- attitude toward the activity.

The short duration of the session with Pleo was not enough to affirm that boredom is avoided neither to explore the novelty effect. However, in line with Kaplan's statement (2005) that few minutes are enough to have a first impression and to take a posture in front of a new object, our results show that children remained attracted and engaged and they neither gave up nor refuse to interact with Pleo.

Curiosity and Exploration

It is to note that some children spent a considerable budget of time checking and exploring the different pieces of complementary material (see Fig. 4-33), guessing its functionality, discussing the meaning of the icons grabbed in the *learning stones*, and inventing procedures to influence Pleo's performance with them. These behaviors are clearly related to the *gaming* behavior but in our coding scheme more focused on interactive behavior towards Pleo are not registered. Nevertheless, when the research question is about engagement all these behaviors have a central role in showing immersion in the game with Pleo and probably could be interesting to include these behaviors in the analyses.

Similarly to the findings in other studies, children in general seemed to expect a higher level of interactiveness, behaviors displays, contingent behavior, flexible and autonomous behavior and social intelligence from Pleo that it is actually able to show without previous training or facilitation (Coninx et al., 2016).

Socialness, Affection and Intimacy

The intimate physical contact with Pleo behaviors (i.e. *Substantial Contact*) were absent except from one occurrence where one girl lifted Pleo to her lap briefly. Thus, the behaviors *Press to Bosom, Hug* and *Carry* were not observed, as well as the dyadic pattern *Cuddle* that also requires substantial contact. These results differs considerably form the similar study carried out in another primary school, with younger children and in a more naturalistic play-like setting where hugging and lifting Pleo –sometimes but not always after asking for permission- was a frequently observed way to interact (Heerink, M., Díaz-Boladeras, M., Albo-Canals, J., Angulo, C., Barco, A., & Casacuberta, 2012). It is remarkable that the only behavior of lifting Pleo and hugging it to the bosom was preceded by the girl (Child_12) asking permission to the facilitator to take the Pleo and immediately ridiculed by her mate (Child_11) imitating grotesquely the movement of rocking a baby in the arms and laughing sarcastically at her. In this case, the childish behavior of nurturing pretend game was immediately punished by her playmate.

Pretend Game vs. Problem Solving Frames

From these findings, we hazard the tentative explanation that children felt too grown up to allow themselves to engage in a pretend game implying taking care and nurturing activities as if in a symbolic play with dolls. In addition, the setting and/or the instructions -the children took part in the experience with Pleo during a science lesson on robotics- may have created expectancies closer to taking part in a technological challenge than in an open-ended pretend game with a robotic pet. Several comments of children seem to support this explanation referring to what had achieved or not previous couples as if was an activity of discovery with rules to be figured out or work through. We identified some confusion and frustration to not understand exactly what we expected from their performance as if it was a challenge to solve or a task to be fulfilled. From these behaviors we could infer that some children felt not only observed but evaluated in their proficiency or skillfulness in using the robot, and even compared to other participants.

Although play analysis show that the most prevalent behaviors was clearly social -showing Pleo objects to engage in interaction-, the interactive modality was not in general emotionally tuned or affectionate. Children were less engaged in nurturing or affection giving behaviors (affective driven behaviors) than in investigation (interest and curiosity driven behaviors). The exception was Child_1 (girl) and Child_4 (boy) that displayed a relatively important amount of clear affectionate behavior (more than the 50% of petting behavior observed was deployed by these two participants) with expressions of protectiveness and tenderness (i.e. baby talk). For instance, the girl (Child_1) *defended* vigorously Pleo twice from her mate's *inappropriate* behavior towards Pleo, even clasping his hand to prevent him to treat Pleo roughly.

Affiliative vs. Non-Affiliative Behaviors

Between aggressive behaviors towards Pleo, *Social Mistreat* appears as a brusque or violent way to catch Pleo's attention, to force it to do something rather than a punishment or an attack. Sometimes children use mild aggressions to coerce Pleo in the frame of an affiliative interaction as to a brusque solicitation of attention or as a reprimand. In one case, the Dyad_6 manipulated very roughly the Pleo, taking turns to twist its neck with violence and repeatedly, with an evident risk to cause serious damage to the robot, while laughing and giggling as if it aggressive behavior towards the robot was an amusing activity.

6.2. Interacting, Engaging and Bonding with Pleo in the Hospital

1. In general, Pleo attires children's attention, curiosity and interest, from babies to teenagers. This attraction lies on different reasons –amazement, wonder, technological curiosity- and at different levels –emotional, intellectual. Pleos easily arise expressions of excitement and enjoyment both in children –patients and relatives- and in accompanying adults and hospital staff. Adults' interest appears not only to support children play but often as an expression of their own interests.
2. This initial interest turns in engaging interaction in most cases, usually mediated and facilitated by adults accompanying, the service providers –researchers and volunteers- and care-givers.
3. From our observations, we identify at least two different playing styles interacting with Pleo: achievers and socializers, following the conventional profiling from the theory of video plays gamification (Bartle, 1996). Achievers are driven by game like aspects as curiosity, challenge, achievement, immediate feedback, rewards and competition. They orient to obtain immediate rewards from the play or from Pleo in terms of funny behaviors, new skills, successful training. On the other hand, socializers prefer more the social aspects of the play and are typically oriented to

affective and nurturing play with Pleo, and they use the game's communicative facilities to converse and interact with other players.

4. Playing with Pleo expands its potential to engage children over time when become a collaborative, collective activity, as an immersive pretend play when every participant can contribute to enrich, sustain and enlarge children interest and enjoyment. Many plays and dramas took place throughout the study, such as cheating Pleo with candies to make it open the mouth and then feed it with less tasty food, introducing other toys or elements like puppets, recreating with Pleo real situations (e.g. healing Pleo's injuries, making Pleo eat the meal).
5. Most common interactive practices with Pleo are feeding related behaviors -putting a finger in Pleo's mouth, cheating Pleo to open the mouth, offering pieces of food or other objects- and substantial contact- embracing, pressing to bosom, and cuddle. The dyadic patterns observed are orient to Pleo's needs: feeding –offering/presenting, putting in the mouth- and making Pleo sleep. We cannot estate to which extend these behaviors are influenced by the researcher's interactive practices, explanations and prompts. Most probably, the fact that the researchers always carry Pleo in their arms increases the frequency of behaviors of physical and substantial contact in children.
6. Children tent to individualize and personalize the robots attributing distinctive features –physical and personality traits- to different Pleos. Sometimes they express preferences as well –as practitioners do, actually.
7. Most children showed the typical behaviors of attachment like seeking for Pleo's proximity, requesting Pleo, asking when they will see Pleo again, resistance and protest for separation, cheering up when meeting Pleo again, reluctance to share, and inventing excuses to retain Pleo a bit longer. In most of these behaviors children count with the complicity of parents and staff to facilitate a new encounter - requesting the staff or looking for the Pleos around the hospital.

6.3. Lasting Relationship and Adopting a Pleo

1. In the case of children that played with Pleo in more than three occasions (i.e. in-patient children at oncological ward), we observed emotional attachment (i.e. seeking for proximity and warmness) and skills acquisition to interact playfully with Pleo. From the field diaries at list two boys had more than seven encounters with Pleo with any sign of loss of interest.

2. On the other hand, in the longitudinal study, the focal interest on Pleo and the actual time spent in interacting with it decayed considerably after the first 10 days, though the girl and the family showed really excited by the temporary adoption, as can be seen in the diaries of the day Nola was delivered to its new family. According to the follow up interviews and reports from Child-Life a tentative reason for this loss of interest is that D. begins to feel weaker just by the time they received the Pleo what had a direct effect in D.'s condition and willingness to play, and an indirect effect on parents' motivation to engage in playful activity with Pleo to sustain children's interest and compensate the natural process of disengagement after the end of novelty. Our guess is that the potential of Pleo as a distractor and a companion over time has to be sustained by other players –relatives, other caregivers or professional staff-, like therapeutic dog's trainers do.
3. From the observations we consider that new ways to play with Pleo have to be disclosed or proposed actively when the indicators of disengagement appear to regain appeal. The children and social close environment had to be empowered with new capabilities as Pleos' trainers. A sound training of new tricks and playful potentiality by parents or adults will be an excellent reinforcement renewing children's interest and opening plenty of possibilities for gamification, such as agility competitions and other challenges for pet-owner's dyads.

6.4. Effectiveness and Appropriation

1. To be adopted by the hospital, a new service or device should demonstrate first of all that do not interfere with the inviolable commitment with children wellbeing and care. Secondly, the service should be compatible with the aims and development of professional care-giving. And finally, the service should evidence a valuable impact of any aspect of children and family experience at the hospital. Pleo seems to satisfy every three conditions with an added value: Pleo very often manages to elicit feelings of closeness and enjoyment on professional staff.
2. Pleos immediately become popular within the hospital community, both in the sense of famous and in the sense of regarded with favor. Soon was stablished a positive and supportive attitude and behaviors towards Pleo –interest, curiosity, liking- , to the service –regulation, appreciation, taking advantage and requesting- and to the researchers –collaboration, help, and appreciation-. We consider that this positive

attitude is a good indicator of the potential of pet-robots to be adopted successfully in children health-care organizations.

3. Pleo's versatility enables it to adopt different roles in children's daily lives:

   – Pleo as a distractor: the novelty effect, the compelling appearance and performance of the robot has an effect of absorbing children's –and bystanders'- attention what, as is well known in pediatric emergencies literature- ameliorates 'per se' the management of a stressful situation
   – Pleo as an outstanding toy: Pleo's unpredictable behavior and its responsiveness to social bids, easily engage children in individual or group play.
   – Pleo as a companion: Pleo expressiveness and responsiveness to affection elicit feelings of warmness and concern.
   – Pleo as a social mediator and facilitator between the different agents involved in the caring process: inpatients, relatives, bystanders, volunteers and clinical staff.

4. The ward influences importantly the way the Pleo-based intervention is perceived and delivered by practitioners, ant the roles attributed to Pleo. Within the hospital there are different micro-communities with noticeable different atmospheres and rules. One main segmentation is between in and out patients, and among the latest, those patients that attend regularly and frequently the hospital (e.g. out-patients undergoing chemotherapy or hemodialysis) and those who just assist to programmed visits (i.e. external consultancies) or emergencies. Children and relatives from these different micro-communities differ significantly in needs (information, distraction, reassurement, comfort), expectations about the service, familiarity with the hospital life, concern about children's condition, among others. Consequently, the activities have to be customized not only to children needs and preferences but also to micro-cultural rules.

5. A very insightful discussion about which units could benefit more from Pleo's company was hold in the focus group and appeared as well in the field notes. On one hand, hospitalized children as well as out-patients in treatment in at least weekly bases (i.e. day hospital) can benefit from a more continuous contact with Pleo that facilitates bonding and the occurrence of behaviors that rarely happens in a first encounter. On the other hand, the familiarity to Pleo makes the novelty effect fade out and interest decreases. Some volunteers consider that Pleo is more effective when children just play with Pleo once or just time to time like in pre-surgery waiting rooms or external consultancies.

6. Researchers and volunteers agree in highlighting the outstanding impact of Pleo in children with especial needs. Successful situations with children with ASD or other development disorders, cognitive impairments, sensory and mobility impairments, children confined in a room or in bed, children weak and sad are reported to respond very positively to Pleo. This estimation is also confirmed by parents' response in amazement and happiness to see their children react, respond to Pleo, interact in different ways and enjoy.

7. Conclusions

This dissertation addresses the emergence of emotional involvement with social robots. More specifically, we investigate the dynamics of child-pet-robot bonding and its application on pet-robot based programs to improve patient's experience in pediatric hospitals. We assume that gaining understanding of the emotional dimension of children-pet-robots relationships would contribute to evaluate its impact in children's lives and to improve robots' design and the effectiveness of robot-based applications for health and wellbeing.

The main outcomes of the thesis are a data driven model of the dynamics of children interacting and eventually bonding with a pet-robot, a behavioral system of child-Pleo dyad interactive behavior, and a naturalistic study in the field at a pediatric hospital to evaluate the feasibility and effectiveness of a robot based intervention to accompany children.

The dissertation starts by a critical review of the state of the art with an emphasis on contributions in the boundaries of different disciplines. From our perspective, the most inspiring disciplines currently in the field of human-robot interaction are ethology, human-animal behavior, design, developmental and social psychology, and social studies of science and technology. From the review we highlight the contribution of ethology to child-robot interaction and bonding research, both substantial –concepts, theories and models- and methodological contributions –research methods and techniques. Moreover, we identify the main gaps and concerns in the field of child-robot lasting relationships with robots.

According to the current state of the art, a data driven integrative model to understand the dynamics of children lasting interactions with pet-robots was developed drawing inspiration from the human-animal bond and more specifically from child-dog relatedness. In the model proposed, bonding is envisaged as an iterative psychosocial process that evolves through three stages –first impression and immediate interaction, short-term interaction and lasting relationship- characterized by distinguishable patterns of behaviors, cognitions and feelings that can be identified and measured. The three stages in the iterative process of gaining intimacy and willingness to interact are defined by specific *challenges* –due to the limiting process in play at micro, meso and organizational levels- and are associated to particular *strategies* to impulse the process. The different factors -individual variables, robot's embodiment and behavior, situational features, the interactive practice- are organized in this framework. From our behavioral perspective, the interactive practice and specifically the sequences of successful reciprocal interaction with the robot –feeding, soothing, and nestling- have a salient role in the impulse of bond forming.

A data driven ethogram was developed containing Pleo's behaviors, children interactive behavior towards Pleo and dyadic sequences of meaningful interaction, as a research instrument to describe and measure children behavior interacting with Pleo. The behavioral system was built up both top-down –from the state of the art and the proposed model- and bottom-up from the empirical data gathered and the video-recorded episodes from pilot studies. This behavioral system proposes as overarching categories engagement and disengagement with the robot. Engagement separates into two more categories in terms of socialness: handle as an artifact and social interaction. Social interaction includes all the affiliative –giving affection, attempts at reciprocity- and no affiliative –agonistic- behaviors that implies attributing the robot a certain degree of social entity. We consider that these highest level functional categories are generally applicable –and therefore useful- to measure child relatedness with social robots, regardless the specific platform and the situational variables. From this level, the behavioral system deploys in finer grained and platform depended units –up to 26 are described and tested- that are specific of child-Pleo interaction.

Finally, an observational study was carried out in the Pediatric Hospital of Sant Joan de Déu in Barcelona to investigate in the field the key processes in a robotic-pet based therapeutic intervention: i) how the robot –a Pleo robot- is interacted by children, families and staff (interactional practice), ii) whether and how this interaction is integrated into the hospital daily practices in a durable way (adoption), iii) how it impacted the caring-network and its practices (appropriation), and iv) how the whole process evolved over time. The study was implemented in coordination with the hospital's Child Life and the head of the volunteers and consisted in an intensive ethnographic study, a systematic observation of a group play session -that was video-recorded- and a follow-up case study of an experience of *adopting* a Pleo.

The results of this dissertation raise the possibility of designing effective pet-robot based interventions in pediatric settings monitoring the process taking into account the dynamics of engagement and bond forming.

The rest of this chapter summarizes the thesis' contributions in two blocks: how children interact with Pleo and eventually engage emotionally, and how a Pleo-based intervention could be acceptable and useful in a pediatric hospital to accompany children.

7.1. Interacting and Bonding with Pet Robots

Human association with personified technologies

– The state of the art about children's relationships with robots presents three main gaps: the lack of knowledge on effects on users when interacting with robots over time, the lack of guidelines for effective and compliant companion robots' design, and, underlying the previous gaps, the lack of a model and a data corpus on long-term relationships with robots.

– The owner/pet-robot frame inspired by human-dog affiliation -the most successful non-conspecific association the humanity has ever built- appears as a very promising approach –not without controversy- to design robots' companionship.

– The knowledge from human-animal dynamics and from pets' behavior can inform robots' design in appealing appearances and behaviors, easy to understand and engaging enough in the long-run to fulfil the role of close companions.

The functional approach to investigate child-robot interaction

Understanding the *reasons why* particular objects and animals have managed to find a niche in our homes over time -demanding non-negligible amount of resources and effort- seems to be a fruitful way to approach companion robots' design. The sequence from the design's perspective would be first investigate *why* –functionality- and then identify which features of the object/animal serve better this function, and finally map them on the robot's embodiment and behavior.

A robot for lasting relationship should be compelling at the first impression and should gain value over time –as novelty effect fades away- through self-reinforcing processes like autonomous development, learning from experience, training, sharing memories, providing users with high renewed experiences, in a virtuous circle: the more one interacts with the robot the more rewarding its company becomes.

No guidelines on robot's appearance and behavior design can be considered regardless the particular frame that makes its presence meaningful. In the case of need-oriented companion robots for children, the owner-pet frame provides children with the one-up role in the relationship that seems to be a good position to support affective and playful lasting interactions, better than human-human inspired frames such as master/assistant, teacher/student or coach/pupil.

Artificial attachment: the tie that binds

The owner/pet frame is based on pet's *selective attachment*, the drive for closeness that manifests promoting proximity and attracting the children to respond to its needs. Typical behaviors are attiring attention, soliciting resources, searching owner proximity, showing emotional states related to the satisfaction of its needs and responding to owner's bids.

To attract children to commit in owner-play activities the robot should appear as an appealing, needy, highly responsive and affectionate creature. To reinforce child's role as an owner the robot should manifest clear preference towards the child in terms of orientation, availability, obedience, and affection.

How children interact with Pleo

- Most children approach Pleo and intuitively engage in interactions related to epimeletic and et-epimeletic behaviors centered in satisfying Pleo's needs –nurturing- providing physical and emotional resources -food, affection, care and entertainment. The more frequent observed dyadic patterns with Pleo are feeding, smoothing, putting Pleo to sleep and bidding it to play.
- These interactive behaviors are facilitated and limited by Pleo's affordances, movements and vocalizations. Child-Pleo interaction develops and reconfigures throughout the encounters that change dynamically the expectations, cognitions, behaviors and subjective experience, influenced as well by social variables.
- The dozens different behaviors and vocalizations Pleo is able to deploy can be pooled into two kind of behaviors i) behaviors to attract the owner attention both in positive ways (funny movements, joyful vocalizations, invitation to play) and negative, like protest (agitation, distress calls) ii) behaviors that express emotions related to the needs satisfaction (hunger, content, anger).
- Two main mechanisms serve owner-pet interaction: Pleo's capability to open the mouth when been presented objects and –eventually- mouthing them when put in its mouth, and its capability to nestle and manifest content when petted and snuggled into substantial contact.
- Interacting with Pleo is a social activity that transforms easily in collective play. In our observations –except from very preliminary trials in the lab- children were always accompanied by other children and adults. In the hospital, the group playing with Pleo adopts variable sizes and configurations combining different players (siblings, mothers,

fathers, other relatives, visits, nurses, volunteers, assistants), taking part more or less actively providing cues, prompts, rules, directions; encouraging, evaluating, appreciating, making sense, interpreting. Frequently, the activity shapes into spontaneous narratives often related to children's daily lives in the hospital. This dramatization enrich the play and enlarge its potentiality of amusement and interactive skills acquisition.

Why do children interact with Pleo

- We consider that the drives and processes that sustain children interaction with Pleo over time are similar to those involved in keeping a real pet, that derive both from pet's and from owner's needs in an intertwined self-reinforcing process. When both needs are satisfied by the same activities (i.e. going out for a walk) or exchanges (i.e. play catch, petting) these rewarding activities will be reinforced. In this context of rewarding interaction, engagement and bonding are likely to appear, as the willingness to keep interacting and the propensity to invest with affection the partner in the gratifying experience.
- Two basic mechanisms sustain child interest in keeping connected with Pleo beyond the novelty effect: enjoyment and social warmness. Enjoyment is the hedonistic feeling based on successfully and satisfactory interactions. Warmness is the gratifying feeling of close companionship and comfort. Both factors can be mutually powered (i.e. the attribution of warm feelings toward us can open a wide range of opportunities for pet-like gameability like offering-getting affection or taking care).
- The unstructured nature of playing with Pleo admits different players' profiles, such as achievers (oriented to immediate rewards and discovery) and socializers (oriented to affective and nurturing play), following the taxonomy of player styles from the theory of gamification (Bartle, 1996).

Companion Pleo: strengths and weaknesses

With rapport to the ideal features to elicit and sustain child commitment with the pet-robot, we list here what we consider the more salient Pleo's strengths and weaknesses.

Strengths

Pleo is able to:

- Express the needy baby animal-like character very effectively and its pet-like condition is immediately and intuitively perceived by users of all ages. Only few children with cognitive or emotional impairments seem to treat Pleo like any other inanimate objects, and very few children rejected its presence and refused to approach.
- Display an extraordinary inventory of bio inspired movements, sounds and vocalizations. In addition, Pleo is able to compound complex behavioral patterns with high naturalistic quality and communicative power that easily provoke astonishment and wonder at first impression (e.g. invitation to play, threat display).
- Convey emotions and distinguishable patterns of behavior that suggest personalities and supports children individualization
- Surprise in subsequent encounters with unexpected new self-driven and/or development behaviors (e.g. walking backwards).
- Inspire attributions and explanations, engage users in guesses and discussions about its essence, personality, moods and intent in playful attempts of making sense of its performance.
- Inspire stories, narratives and imaginary worlds (dramas and myths) as an immersive pretending play, inventing news scenarios (i.e. home, farm), introducing new actors (i.e. other Pleos or toys).
- Engage not only children but also adults in many ways satisfying different partners' interests at rational and/or emotional levels (technological curiosity, wonder, tenderness, sympathy) keeping them interacting with Pleo "in different worlds both real and symbolic" (Pitsch & Koch, 2010).

Weaknesses

- Pleo's performance lacks consistence in response to users' interactive behaviors and social bids (contingency) that may result in frustration and misleading inferences (superstitions) that jeopardize the acquisition of effective practices.

- Pleo does not orient to visual and auditory stimuli from the environment and most importantly, from its master. Some of Pleos' responses and behavioral changes are too subtle to be correctly understood and even detected by users (i.e. sounds in a noisy environment). Development patterns that supports the illusion of growth and learning are not easily identified.
- Pleo's learning capabilities are very limited in real scenarios. The protocols to acquire new behaviors and tricks are not intuitive, should be trained and, most importantly, are neither robust nor contingent on users' behaviors in the wild.
- Pleo has important mobility limitations in the frame of an active baby-pet. Main social and meaningful behaviors in the owner-pet situation such as approach/withdraw, follow up, forage, exploration or play catch are not possible.
- Pleo's unexpected behaviors have an undoubtable appeal in the first stages and contribute to life-likeness and autonomy but fail to engage children in sustainable interaction that need more consistent patterns. Erratic behaviors that cannot be predicted or understood break the illusion of mastering a smart, obedient pet and can result in frustration and disengagement.

7.2. Pet Robots Interventions for Patient Children Wellbeing

Serious Pleo: managing bond forming for companionship

As we have mentioned above, though there are many ways to enjoy playing with a robotic pet, we consider that forming an emotional bond with the pet-robot is a desirable *add on* in the case of robots that are supposed to accompany children in a long-term bases for therapeutic purposes (Fernaeus et al., 2010).

Bonding with a pet robot is not a process that occurs necessarily when children are *exposed* to its presence, but the result of experiencing gratifying episodes of interaction with it. To facilitate the emergence of an emotional bond, the intervention has to be planned to identify the particular challenges that are faced and to implement effective strategies to overcome this challenges. Lessons learned from previous studies on long-term personal robots *cohabitation* and the present research give some hints to monitor this process and to avoid dead ends. Two main mechanisms can be highlighted in this process: the robot's ability to engage in reciprocal sequences with children and its capacity of learning from training. In this context, the way Pleo is presented and played by the other agents involved –mainly adults- is crucial to sustain –and even increase- Pleo's *experienced value* over time.

Compatibility and acceptance

Our results support our initial assumption that the pet-robot intervention with Pleo robots i) is compatible with the practice of professional and informal care givers in the hospital, always under the supervision of nursery, ii) is accepted and appreciate by families, and last but not least, iii) provides valuable experiences of amusement, distraction and enjoyment to children and therefore contribute to their wellbeing. In addition, the occurrence of attachment behaviors towards Pleo –proximity seeking, requesting Pleo, sorrow for the separation, greeting for reunion- indicates that emotional bonding with Pleo appears frequently though not always and rely considerably on the attitude and active participation in the play of other actors as relatives and care-givers.

Effectiveness

Three different roles have been observed during Pleos' deployment: i) Pleo as a *distractor*: the novelty effect, the compelling appearance and performance has an effect of absorbing children's –and bystanders'- attention what ameliorates *per se* the management of stressful situations, as is well known in pediatric emergencies literature ii) Pleo as an *augmented toy*: Pleo's unpredictable behavior added to its responsiveness to social bids, easily engage children in individual or group play, iii) Pleo as a *companion*: Pleo expressiveness and responsiveness to affection elicit feelings of warmness and concern and iv) Pleo as a *social mediator*, facilitating the communication between the different agents involved in the caring process.

Pleo and children with special needs

Both researchers and volunteers agree in highlighting the outstanding impact of Pleo in children with especial needs. Pleo supports different modality of active and passive interaction: auditory, tactile, visual and therefore may adapt to specific children preferences and capabilities. Successful situations with children with ASD or other development disorders, children with cognitive, sensory and mobility impairments, children confined in a room or in bed, children weak and sad, are reported to respond very positively to Pleo, according to researchers, clinical staff and parents' estimates.

Summary of contributions

To wrap up this section, we summarize our work into the four following contributions:

- An integrative model of child-robot interaction where key concepts as engagement, attitudes, expectations, attachment, and social influence can be organized to gain understanding of child-robot interaction over time.
- A comprehensive inventory of Pleo, children and dyad behaviors that can be applied to study systematically the interactional surface of children sociality with robots in other contexts and with other platforms, highlighting the importance of analyzing not only child's behavior but also robot's actual performance.
- A social approach to child-robot interaction with Pleo that is a robot to be played collectively to exploit their most powerful features.
- Empirical data on children, parents, and professionals' behaviors with and opinions towards Pleo, gathered ecologically in the wild from direct observation, interviews and focus groups, in the context of a therapeutic intervention.

8. Limitations and Further Research

- The ethograms –tested, discussed and adjusted in this work- would benefit from further iterations to be refined and to assess its reliability.
- The dyad's behavior analyses would benefit from further systematic contingency and sequential analyses to investigate associations between behaviours and identify patterns.
- The in the field study was conducted in a single pediatric hospital. More studies need to be conducted to assess whether the findings on bonding dynamics and the use of robotic pets as an assistive resource can be generalized to other pediatric settings.
- The same cautions should be taken concerning to extend the results to other contexts in children's lives. Although the model of bond forming aims to be generic, the hypothesis of its applicability to other contexts–schools, homes- remains invalidated,
- Further studies will be necessary to complement the observational analysis of children behavior with the study of their cognitions and feelings towards Pleo (i.e. expectations, attributions, affection).
- Further studies will be necessary to measure the impact of the pet-robot intervention both in terms of children bonding –inspired by human-animal bond measurements- and in terms of clinical outcomes (i.e. optimism, perception of health, anxiety, perception of social support) –inspired by hospitalized children quality of life research.

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Tables

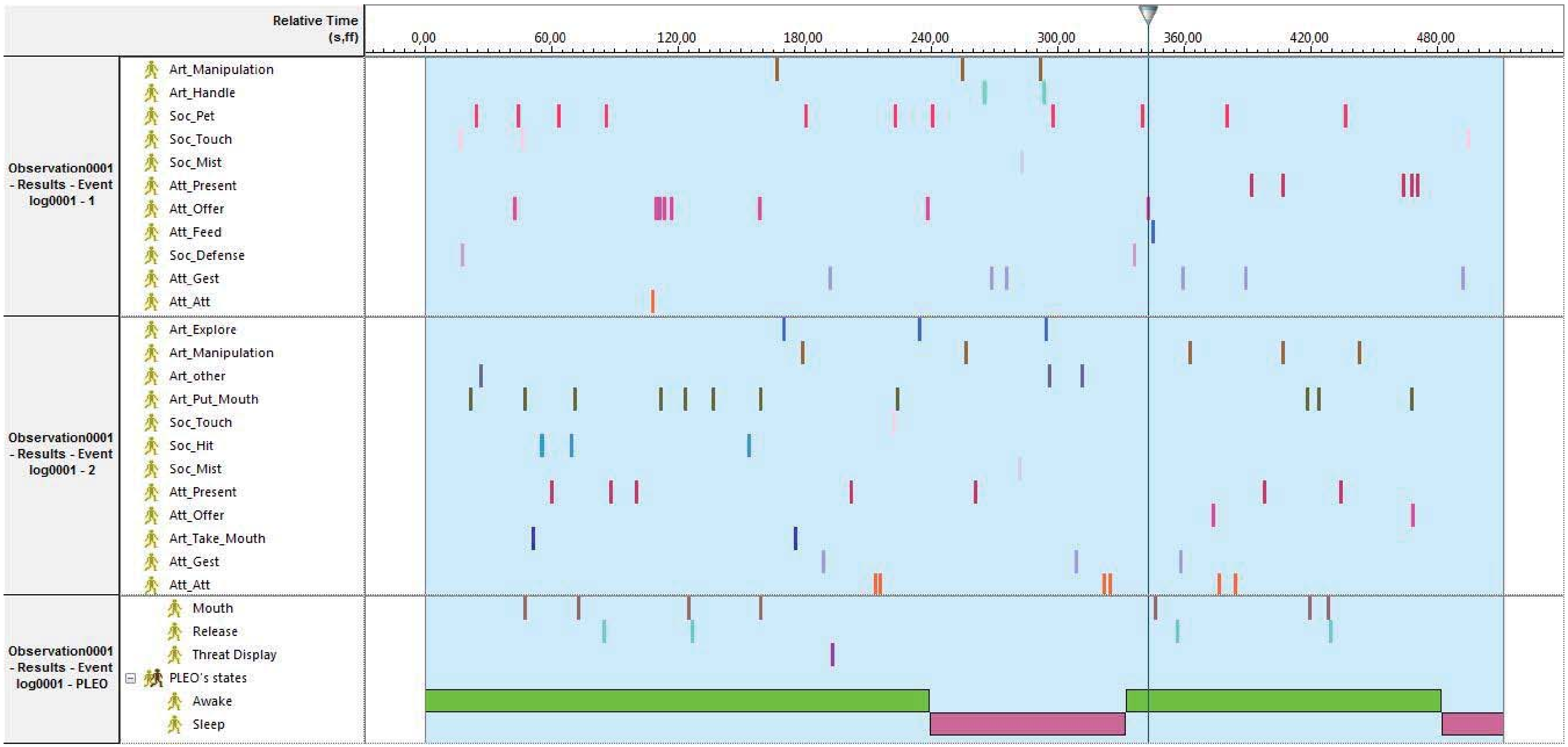
Figures

Appendix A

Plots of triadic interaction

In this appendix, we present the plots obtained from the observational analyses of the 6 sessions of children playing with Pleo in pairs. Every plot represents the three subjects' synchronized sequences of behaviours and states during the session.

In the left, the coding scheme displays only the behavioral units observed for each subject. Therefore, the height of each participant row indicates the amplitude of behavioral variability.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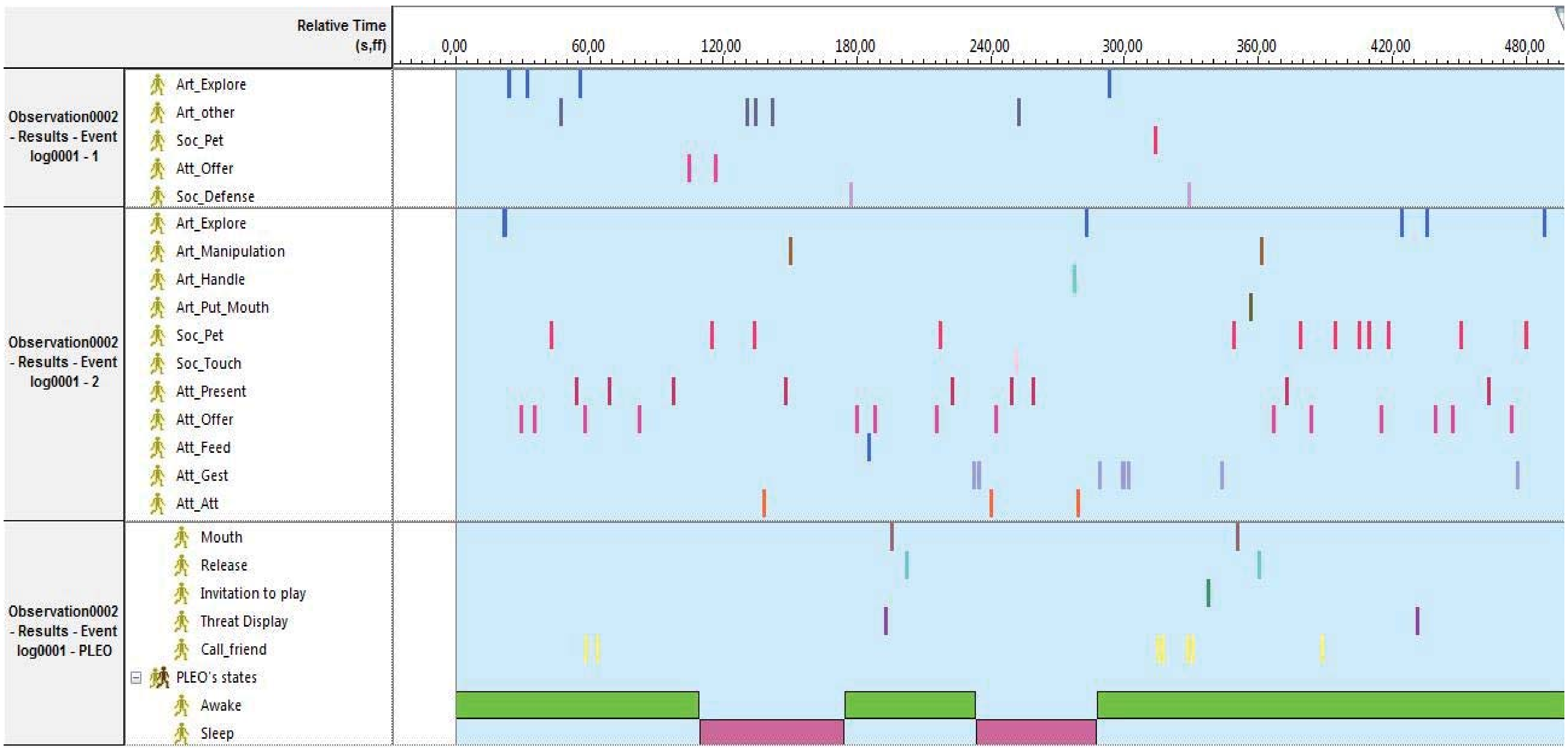
60,00
120,00
180,00
240,00
300,00
360,00
420,00
480,00
Observation0001 - Results - Event log0001 - 1
Art_Manipulation
Art_Handle
Soc_Pet
Soc_Touch
Soc_Mist
Att_Present
Att_Offer
Att_Feed
Soc_Defense
Att_Gest
Att_Att
Observation0001 - Results - Event log0001 - 2
Art_Explore
Art_Manipulation
Art_other
Art_Put_Mouth
Soc_Touch
Soc_Hit
Soc_Mist
Att_Present
Att_Offer
Art_Take_Mouth
Att_Gest
Att_Att
Observation0001 - Results - Event log0001 - PLEO
Mouth
Release
Threat Display
PLEO's states
Awake
Sleep



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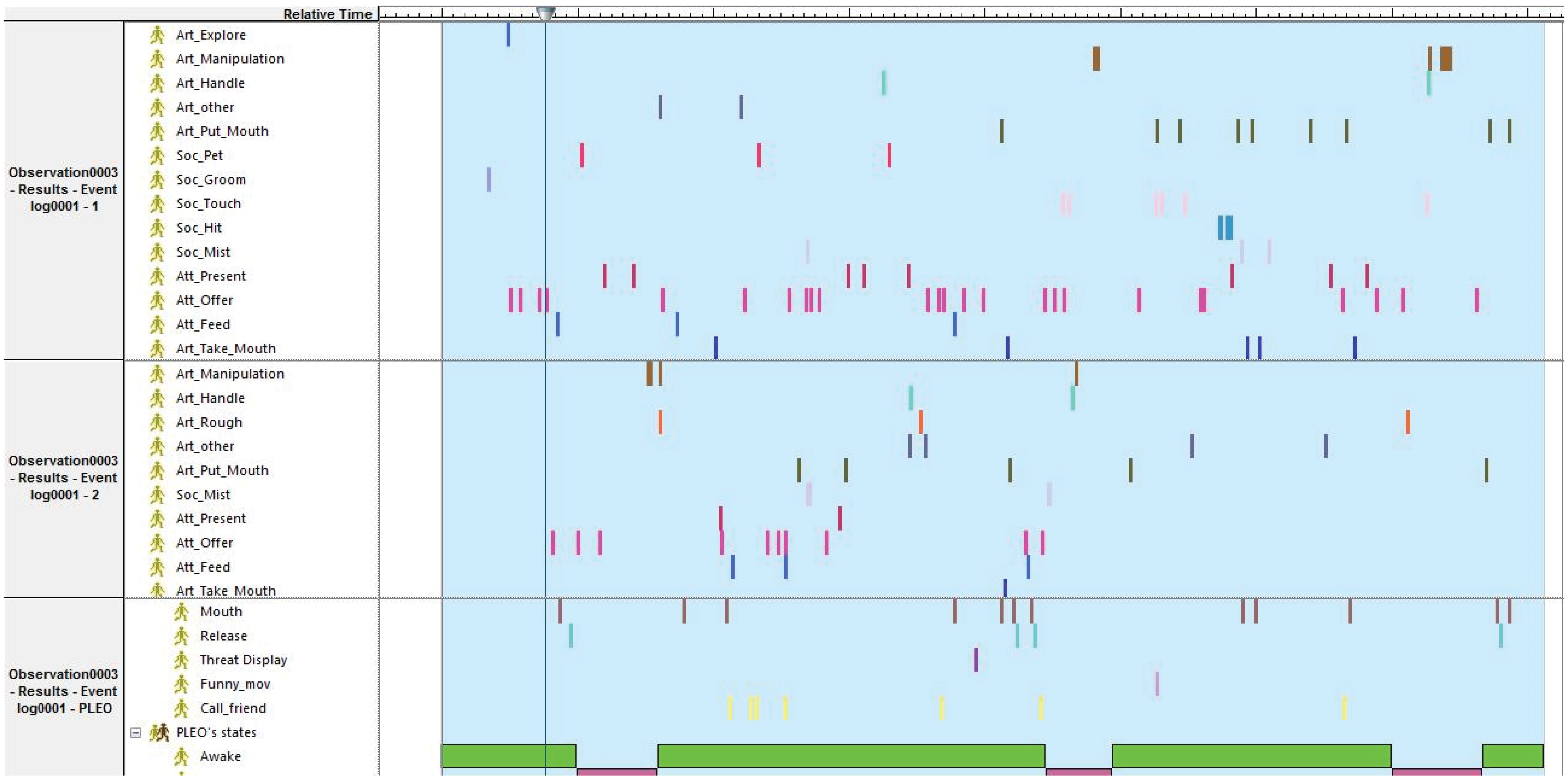
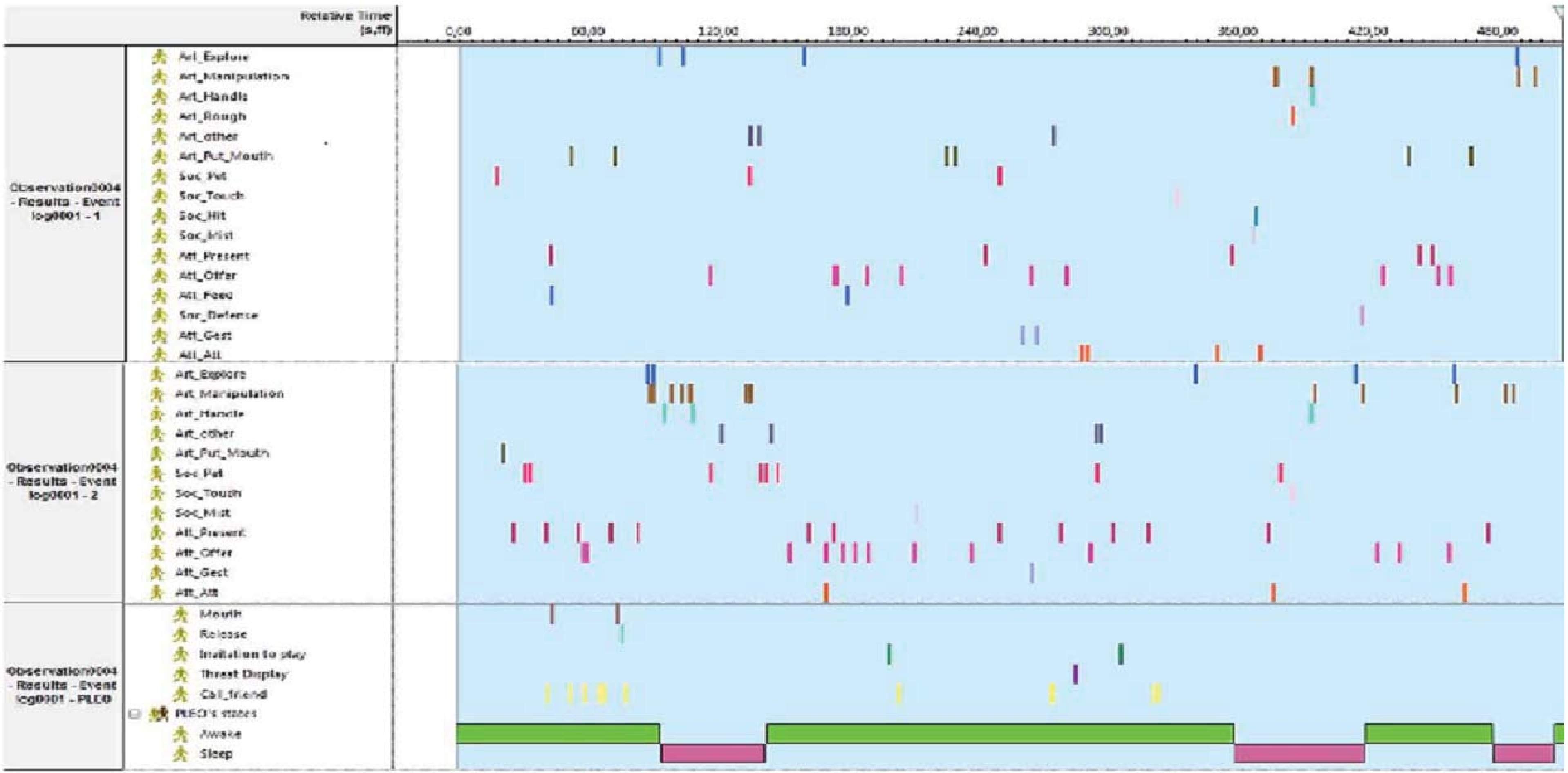
(s,ff)
0,00
60,00
120,00
180,00
240,00
300,00
360,00
420,00
480,00
Observation0002 - Results - Event log0001 - 1
Art_Explore
Art_other
Soc_Pet
Att_Offer
Soc_Defense
Observation0002 - Results - Event log0001 - 2
Art_Explore
Art_Manipulation
Art_Handle
Art_Put_Mouth
Soc_Pet
Soc_Touch
Att_Present
Att_Offer
Att_Feed
Att_Gest
Att_Att
Observation0002 - Results - Event log0001 - PLEO
Mouth
Release
Invitation to play
Threat Display
Call_friend
PLEO's states
Awake
Sleep



Relative Time
Observation0003 - Results - Event log0001 - 1
Art_Explore
Art_Manipulation
Art_Handle
Art_other
Art_Put_Mouth
Soc_Pet
Soc_Groom
Soc_Touch
Soc_Hit
Soc_Mist
Att_Present
Att_Offer
Att_Feed
Art_Take_Mouth
Observation0003 - Results - Event log0001 - 2
Art_Manipulation
Art_Handle
Art_Rough
Art_other
Art_Put_Mouth
Soc_Mist
Att_Present
Att_Offer
Att_Feed
Art_Take_Mouth
Observation0003 - Results - Event log0001 - PLEO
Mouth
Release
Threat Display
Funny_mov
Call_friend
PLEO's states
Awake



Relative Time (s,ff)
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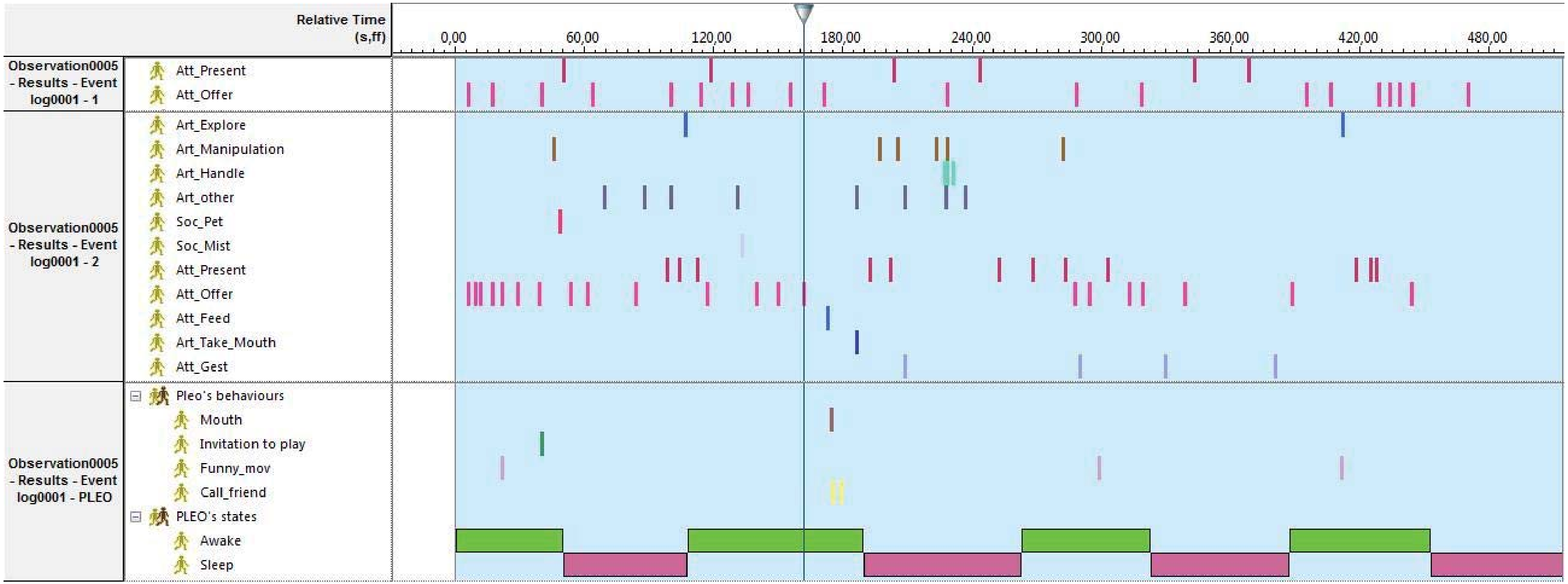
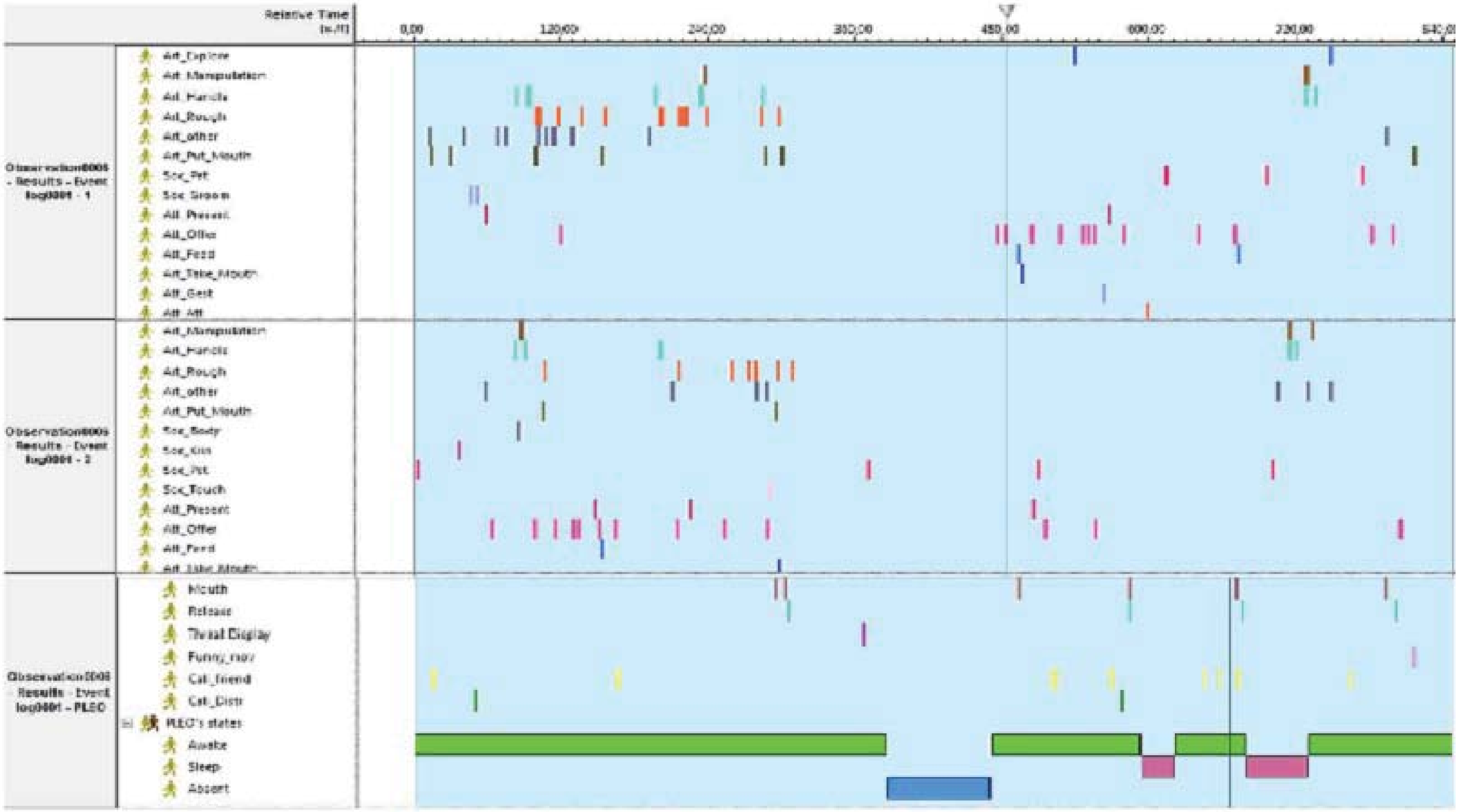
60,00
120,00
180,00
240,00
300,00
360,00
420,00
480,00
Observation0004 - Results - Event log0001 - 1
Art_Explore
Art_Manipulation
Art_Handle
Art_Rough
Art_other
Art_Put_Mouth
Soc_Pet
Soc_Touch
Soc_Hit
Soc_Mist
Att_Present
Att_Offer
Att_Feed
Soc_Defence
Att_Gest
Att_Att
Observation0004 - Results - Event log0001 - 2
Art_Explore
Art_Manipulation
Art_Handle
Art_other
Art_Put_Mouth
Soc_Pet
Soc_Touch
Soc_Mist
Att_Present
Att_Offer
Att_Gest
Att_Att
Observation0004 - Results - Event log0001 - PLEO
Mouth
Release
Invitation to play
Threat Display
Call_friend
PLEO's states
Awake
Sleep



Relative Time (s,ff)
0,00
60,00
120,00
180,00
240,00
300,00
360,00
420,00
480,00
Observation0005 - Results - Event log0001 - 1
Att_Present
Att_Offer
Observation0005 - Results - Event log0001 - 2
Art_Explore
Art_Manipulation
Art_Handle
Art_other
Soc_Pet
Soc_Mist
Att_Present
Att_Offer
Att_Feed
Art_Take_Mouth
Att_Gest
Observation0005 - Results - Event log0001 - PLEO
Pleo's behaviours
Mouth
Invitation to play
Funny_mov
Call_friend
PLEO's states
Awake
Sleep


Relative Time
0,00
120,00
240,00
360,00
480,00
600,00
720,00
840,00
Art_Explore
Art_Manipulation
Art_Handle
Art_Rough
Art_other
Art_Put_Mouth
Soc_Pet
Soc_Groom
Att_Present
Att_Offer
Att_Feed
Art_Take_Mouth
Att_Gest
Att_Att
Soc_Body
Soc_Kiss
Soc_Touch
Mouth
Release
Threat Display
Funny_mov
Cat_friend
Cat_Distr
PLEO's states
Awake
Sleep
Absent

Appendix B

Transcriptions of children verbal behavior

In this appendix, we present the verbatim transcriptions of the verbal behaviors and the contextual information from the observational analyses of the 6 sessions of children playing with Pleo in pairs

Text in bold is the verbal production. Text between square brackets accounts for nonverbal behavior or contextual information. In the right column, in bold Pleo's utterances and verbal production of other presents, in italics Pleo's behavior codes, as stablished in the coding scheme.

Abbreviations are as follows: Fac = Test facilitator; Res=Researcher; [...] = Verbal utterances not understood. The episodes of contingent exchange (*Dyadic Patterns*) are highlighted in yellow. The rows do not represent a time unit, but the position of every event reported in the sequence of the behaviors.

OBSERVATION 1 (OO) Child_1 and Child_2

Min Seconds	Child 1	Child 2	PLEO's behavior / Contextual information
1 1-60	**¡Hala! ¡Qué pasada! ¡Qué guay!**		
		¿Esto come?	
	[Laugh][i]		
	[Laugh]	**No llores, ¡tonto, malo!** [pessiga la pell del llom del Pleo]	
	Es de plástico		
		Esto come?	
	¡No sé!		
		¡Come, come!	
		Juega un poco con esto	
			Mouth
		Eh muy bien!	
	[Laugh]		
2 60-120		**No te comas ...**	
		Come, come	
			Mouth
		Muy bien!	
	Está comiendo!!		
		Lo ves! Como está comiendo	
			Release
		Lo voy a hipnotizar... [amb el tug]	
	[Laugh]		
		Yo pensaba que lo iba a hipnotizar	
	!Mira! [mostra learning stone]		
	Se lo tiene que comer		
3 120-180	**Pone tres** [mirant learning stone i fent 3 amb elerning stones dits]		
		[dona Sugar Cane]	
		Dale una hoja	
			Mouth
		Dale de comer	*Release*
	Ay mira! Aquí pone...		
		[Pega al Pleo]	
	¡!!No le molestes!!! [li pega a la mà]		
			Mouth
4 180-240		**Esto si le pones un tres**	
	Que no!! [li retira la ma]		
			Threat Display
	[Laugh]		
		¡Qué te he dicho!	
		Esto pone... Una pelota grande...	
		Esta no, déjala	
	Espérate un momento... esto puede que		
		Qué fuerte,	
	¡¿te quieres esperar un momentito?!		
	¿Esto qué es...?		
			Pleo: **Beep** *Sleep*

5		**Qué pasa aquí!**	
240-300	**Yo no he hecho nada, !eh!**		
	[Laugh]		
		Esto se ha muerto!	
	[Laugh]		
	... a ver si me lo cargo un momentito...		
		Que haces!	
		A ver, vamos a intentar reanimarlo... [va remenant peces]	
	[...]		
		Así se queda dormido, y para despertarlo...	
		Jo que se...	
6			
300-360			
			[Entra Fac[ii].]
	S'ha mort no, oi? [a la Fac:]		
			Fac: **S'ha apagat**
	Ah, ja deia jo...		
	Es igual		
			Awake
	[S'espanta] [Laugh]		
	Holaaa!		
		Ara que no está durmiendo ves	
	Es veritat!!!! Mira		*Mouth* [Leaf] *Release*
			[Raises front leg]
	Mira! La pata! [Assenyalant pleo]		
		Depende de lo que haga,por ejemplo sy yo pongo un 3 [posa 3 dits] **Hace más cosas** [ensenya 3dits]	
	[ensenya 3dits]		
7			*Threat Display*
360-420	**¡Qué guai!**		
		Se ve que no tenia ganas de comer	
		¿Has visto?	
		Qué más?	
	[ensenya 3dits]		
		No creo que lo quiera...	
	[Laugh]		
	Dame las piedras estas		
	[Ensenya les dues mans]		
	No hagas [...] [li dona un cop a la ma]		
	Què esta haciendo?		
		Pues comer! Mira tiene hambre	
		¡Come!	
			Mouth
8		[Li pren]	
420-480	**Estaba comiendo, estaba comiendo**		
		[li dona]	*Mouth*
			Release
			[Tail up and down]
	Mira la cola! [pointing to the tail]		
	[Laugh]		

		Se le va a romper el cuello [Pleo turns the head to one side]	
	[li ensenya les mans]		
	¿Has visto?		
		Pleo xx xx [llegeix la ID]	
		Y este bambú?	
9			*Sleep*
480- 540		**¡¿¿Ahora se pone a dormir??!!**	
	¿	**Pero ya lo has hecho dormir** **Puah! Se ha dormido!!** [Frustration]	
	Esto? [mostra canya sucre]		
			Fac **Ja està**

OBSERVATION 2 (PP) Child_3 and Child_4

Min Secs.	Child 1	Child 2	PLEO's behavior/ Contextual information
PP			
1	[Laugh]		
1-60	[Laugh]		
	[Laugh]		
		Te una càmara en el nas, crec	
		¿Que tiene que comer o algo parecido?	
		Come	
		Come	
	[Laugh]		
		Come	
			CallFriend
		No no le gusta	
	[...]		
	[Laugh]		
		Come	
		¿però què tenim que fer?	
		¡Darle piedra!	
		Come	
2		[com susto] **Oi!**	
60-120			Pleo: **Uh Uh Uh!!!! Uh Uh Uh!!!!**
	[Laugh]		
		Te gusta esto [show tug of war]	
		Que tenim que fer?, ens han dit que juguem [a la Fac]	
			Fac: **Jugueu**
		Come	
		Aqui hay dibujitos [lerning stones]	
		Hi ha dibuixets	
		A ver, voy a probar...	
		Dice que le pongas la mano	
		si	
	No aquesta		
		Y esto	
		Que pone la rodilla, a ver [scrtachs Pleo's back]	
			Pleo: ***Beep*** [Sleep]
		¡Uy uy uy! Lo he tocado, se ha muerto [snaps fingers]	
	[Laugh]		
3		**Come**	
120-180	[Laugh	[Laugh]	
		Se murió	
		Mira he hecho asi, mira [touching Pleo's back]	
		Ha hecho así, ha hecho *beep* i se ha muerto	

		[snaps fingers at Pleo's face]	
		Y esto que es? [ID card] **¡Ah! Pleo ya lo he visto anunciado. Que con esto también hace algo. ¡Ábrete!! Fiu!** [rub's the Pleo back] **¡Fiu!**	
		S'ha mort [a la Fac:]	
			Fac: **S'ha parat**
			Fac: [fa l'ON]
		¡!Ahhhhhhh!!!!	
			Fac [marxa]
		A ver si descubrimos algo... Por qué a ver aquí dice que canta i que mueve la pata y aquí que... [checking the learning stone]	
	Que li donis de menjar		*Call Distress*
		¡Ay ay ay! Que se mueve! [ensurt]	
		A ver, tu, come	
4			[Almost] *Mouth*
			Release
180-240		**¡Mira! Ha comido más o menos**	
		Se mueve pero no hace mucha cosa que digamos	
			Threat Display
		¡!No me comas!!	
			Mouth
			Release
		y ahora para que se la trague	
		¿Esto que es bambú?	
		Dime, ¿qué quieres comer?	
		Dice que le pongas la mano [puts the hand beneath Pleo's jaw]	
		I pal	
		¡Tres! [show three fingers]	
			Sleep
		Se ha muerto otra vez!	
	[Laugh]		
		Està dormint	
5		[Snap fingers] **¡¡Despierta!!**	
240-300		**¡Hoja de... Hola! Es de goma esto** [training leaf]	
		y con números. Vale. ¡Fiu! ¡Fiu! [rubs Pleo's back with the leaf] [touch Pleo's belly]	
		¡Despierta, despierta!	
		[snap fingers]	
		A ver si esto es para hipnotizarlos	
		¿Qué pone? "Pleo"	
		Con el 3 ésta es la más sencilla porque ya te dice	Fac: [turn Pleo On]
	[...]	**A ver**	
		[snaps fingers] **¡Despierta!**	
		Tú, que te digo que hacer el número 3. ¿¿Qué me oyes??	
		Tres [3 dits]	
		Tres	

		[3 dits]	
		Tiene una cámara aquí por eso me mira	
		Tres [3 dits] **Tres, a ver qué haces**	
6		**Mueve la cola**	
300-360		**Tres**[3 dits]	
		¡!Oi!! ¡!que es bonito!!! [baby talk]	
		A ver si es como un perrito que te gusta esto [scratch chin]	
			Pleo: **Uh Uh Uh!!!! Uh Uh Uh!!!!**
		¡Uy Uy Uy¡ [startles, backs away]	
		Y si son pasos lo que tienes que hacer	
			Pleo: **Uh Uh Uh!!!! Uh Uh Uh!!!!**
		¡Siii! Ahora canta, mira está haciendo esto. I ahora hace esto	
			Invitatation to play
		Per fer això els hi deu haver costat molt...	
		Mira come	
			Mouth
			Release
7		**I això que, també menges fulles tu?**	
360-420			Pleo: Vocalises
		[mimicks Pleo] **¡Ah! Ja se lo que quieres, hielo**	
		Tienes frio [rub Pleo's back with the piece of ice]	
		[xxx]	
		Hala mira hay dos iguales [leaves] **¡Ten! Come, come**	
			Pleo: **Uh Uh Uh!!!!**
		[mimicks] **¡Hu Hu Hu!**	
		[petting Pleo] **A ver si es como un perro** [petting Pleo]	
		Si tiene sentido del tacto	
		I si le tocas hace cosas	
		¿Qué buscas?	
8	**[...]**		
420-480		**¡!Pocholete!!**	
		Si tiene una cámara, ves? Y en la nariz tiene también unas cosillas	
		Mira	
			Threat Display
		[Laugh]	
		Come, come	
		Y esto te gusta?	
		¡!No, no!! no te mueras	
		Venga que te vamos a lo que te hacia antes	

		Ves, antes se movía cuando le hecho esto [petting]	
	[...]		
		Jo tampoc, pero es per que et facin cosetes	
		Esto parece una pelota [tug of war**]**	
		Es inteligente, eh?	
		Come	
		Tres	
9		**No no no te mueras, a ver como se hace, no cierres los ojos**	
480- 540			Fac vale ja esta

OBSERVATION 3 (QQ) Child_5 and Child_6

Min Secs.	Child 1	Child 2	PLEO's behavior/ Contextual information
QQ			
1	**Què fem?**		
1-60		**Això va sol o...?**	
	I que tenim que fer?		
	¡Ah, mira! que aquí tiene la cámara		
		¿Que es suposa que tenim que fer?	
			Fac: **Jugar**
	Hala! què xulo!!		*Mouth* *Release*
2		**El tío se ha *quedao* frito**	
60-120			**Beep** *Sleep*
		Oye se ha quedao dormido [a la Fac:]	
			Fac [Turns on Pleo]
		Tócale [...]	
			Awakes
3			*Mouth* ID
120-180	**¡Suelta!** [al Pleo]		
			Mouth LERNING STONES
		¿Y que son estas piedras? [the learning stones]	
		¡Ay mira! esto es para que cante	
			Pleo: **Uh Uh Uh!!!!** **Uh Uh Uh!!!!**
			Mouth LERNING STONES
	[Laugh]		
	Esto es *pa* que duerma		
		No se la des entonces	
	Se ha *quedat* traspuesto		
	A ver. A ver ésta... A ver ésta, espera ¡!espera!! ¡Ah! ¡Vale todo por las piedras!		
4 180-240		**¿Pleo?** [read]	
		Hay una que lo deja dormido	
	Ya...		
	Ten		
			Mouth Leaf
		Tú, tonto	
		[...]	
5			
240-300			*Mouth* LERNING STONES_ [in addition to the leaf]
			Mouth Leaf
	Vocalize mimicking Pleo		
	¿Y esto? [Tug of War]		
		Esto se supone que no le gusta porque si la tira...	
	No, le gustan las de colores		*Mouth* Leaf *Release*

	A ver, prueba con la de color		
		Se ha dormido	
	Es que le he puesto yo [...]		
		Aquí [Turning Pleo on]	
	Pues si esta encendido...		
			Pleo moves
6	**¡Ahora!**		
300-360	**Quiere comer**		
	Mira, le gusta...		Shake the tail
		¡Si está bailando!	
		Mira esta, esta es para jugar	
	¿Hueles?		
7			*Mouth* Leaf
360-420		**[...]**	
	No sé...		
			Mouth Leaf
	¡Mira! Estaba jugando con él, ¡mira!		[Tug amb full]
			[Tug amb dit]
	Mira ¿hacemos la que cante?		
			Pleo: **Uh Uh Uh!!!!**
			Mouth Leaf
8		**Para dormir es esto ¿no?**	
420-480	**¡ Ah!! Vale ya sé de dónde. Vale, vale...**		
			Pleo: **Beep**
			Sleep
	Se duerme [Turn Pleo on]		
	Vale. No se despierta		
			Awakes
	Si esto pues no sé, lo coge		
		Déjaselo a ver qué hace	
			Mouth ID
			Release
9	**No le ha gustado**		
480- 540	**Espera otra vez**		
			Mouth ID
			Fac: **Vale doncs ja s'ha acabat**

OBSERVATION 4 (RR) Child_7 and Child_8

Min Secs.	**Child 1**	**Child 2**	**PLEO's behavior/ Contextual information**
RR			
1 1-60	**¡!Qué mono!!**	**¡Ay que cosita!**	
	Això es pel video		
			Mouth
			Release
		Se ha *apagao*	
	[...]		
2			
60-120		**No se**	
			Beep *Sleep*
3			Fac: gets in
120-180		**Una cosa...** [a la Fac:]	
			Fc: **Digues**
		Com va això?	
			Fac: **Com vulguis provar-ho. No se. ¡ A veure si m'ho ensenyeu vosaltres a mí!**
		[...]	
			Awake
	Bienvenido a la tierra [hold the ID card in the hand]		
	[...]		
4	**¡Ah vale!**		
180-240			*Invitation to play*
	[...]		
	[...]		
5 240-300			
	[...]		
	Pica el terra	**[...]**	
	[show 3 fingers]		
		[show 3 fingers]	
			Threat Display
	[Banges on the floor]		
	[Banges on the floor]		
6 300-360		**[...]**	
			Invitation to play
	[...]		
		Mira	
	[whistle]		
	[snap fingers]		
		[snap fingers]	
	[whistle]		
	Més?		
			Beep
			Sleep
7	**Ah! Vale**		
360-420	[Claps the hands]		
		[claps the hands]	
		Què?	
			Fac: **Tu mateix!**
	Aquí!		
	Ja està!		

	***Pera, pera*! le doy la vuelta**		
		Parece que estés metiendo el dedo por el culo [manipulate to turn Pleo on]	
8	**[...]**		
420-480	**Esto mira...**		
			Beeps *Sleep*
9			Fac: **Vale s’ha acabat l’estona de joc**
480- 540			

OBSERVATION 5 (SS) Child_9 and Child_10

Min Secs. SS	Child 1	Child 2	PLEO's behavior/ Contextual information
			Fac: P**odeu jugar amb ell**
1		**Valeee**	
1-60			
	[...]	**Hellooo!**	
		No come ni nada. ¿Esto es como una piedra? [takes the salt]	
	[Laugh]	[Laugh]	
	Que xulo!		
			Invitation to play
		Mira, vas a cantar	
			Sleep
	Ah! Está durmiendo		
2		**Concéntrate...!** [with the *tug of war*]	
60-120	Esto tiene que ser **[...]**		
		Despierta!	
			[entra la Faci posa en ON]
	Gràcies		
		Despierta!	
			Wakes
		Concéntrate	
	Oi!		
3	**¡Ei! ¡Que come, que come!**		
120-180		**¡Ahora!**	
	[Laugh]		
	Ah! ahora		
		Este	
	[...]		
		[...]	*Mouth* **Uh Uh Uh!!!! Uh Uh Uh!!!!**
	[Laugh]		
		¡Qué guay!	
			Uh Uh Uh!!!!
	[Laugh]		
		[...]	
4			
180-240			*Sleep*
	Se ha muerto otra vez		
	¿Esto qué es? [Tag of war]		
	Y lo de los tres dedos		
		No se	
		Es para "*concéntrate*"	
	¿Este no será para dormirse? [lerning stones] **Porque siempre que le hemos hecho este se ha dormido**		
	Este es para [...] y este para [...]		
5			
240-300			[Faci gets in and turns Pleo on]

			Wakes
	¿Dónde esta [...]?		
		Aquí	
	[Laugh]		
			Funny movements [Move tail side to side]
	¡Mira la cola!!		
6		**¡Qué guai!**	
300-360	**Esto es como una [...]** [es refereix al tug]		
		Hombre es su nombre. Hombre es su nombre	
			Sleep
		Ronca. Ahora ya no	
	Otra vez se nos ha dormido		
	¿Por qué le haces [...]?		
	[...]		
	¿Y estos números?		
		Aquí tiene ...	
7	**Piedra y piedra**		
360-420			
			[Faci gets in and turns Pleo on]
			Wakes
	¡Ah! ¡Mira! ¡Qué chulo!		
			[Raise front leg]
	[puts the sal under Pleo's paw]		
		[Laugh]	
	[Laugh]		
8		**[...]**	
420-480		**[...]**	
	[...]		
		[...]	
			Sleep
		[...]	
	[...]		
		[...]	
		[Laugh]	
	[Laugh]		
9		**[...]**	
480- 540	**[...]**		
		[...]	
	[...]		
			Fac **Bueno ja s'ha acabat l'estona de joc**

OBSERVATION 6 (TT) Child_11 and Child_12

Min Secs.	Child 1	Child 2	PLEO's behavior/ Contextual events
TT			
1			
1-60			Fac: **Com vulgueu vosaltres**
	Això que és? [to the Fac]		
			Fac: **No ho se**
		[...]	
	[...]		
		Ets molt guapo	
2		**¿Pero què s'ha de fer?**	
60-120	**Jugar**		
	¿Qué pasa si lo cogemos?		
		¿Es pot agafar?	
	¡Ay que susto!		
	¡Ay que te muerde, que te muerde!!		
	Yo pensaba que te iba a hacer un susto cuando te ha dicho pots agafar...		
	Se ha parado		
3	**Como ruge**		
120-180	**Tranquilo...**		
	¿Aixo que es una fulla perque ho has vist?		
	Pleo		
	¡Ah mira! pero com es menge... com es fa que es mengi això. Pero no masstega, ho tira		
		Es un tronco [the sugar cane]	
	[...]		
		¡Tú!, ¡come!	
	Estas... ¿Tienes calor? Es hielo		
4		**Es que això no es pot fer**	
180-240	**¡Pero si te ha comido...!**		
	[...]		[PLEO comença a fer soroll de bloquejat]
		[...]	
	[...]		
		Ponlo bien	
	¿Esto es lo que ha hecho la Mireia?		
		No se	
	Mira: "Pleo" Pleo!		
	Ah mira que tiene [showing Pleo's belly]		
5			
240-300	**[...]**		
		[...]	
			Fac: **No li estireu tant per que [...] el cap**
		Vale	
			[Episodi maltractament]
			Mouth Fulla
	Es que si se la metes [...]		
6			*Mouth* Fulla
300-360		**[...]**	
		Així no es pot jugar...	
			[Entra Researcher]
		Aixo no es pot jugar	

			Res: **S'ha quedat aixi?**
		Si se'n va	
	¿I tota l'estona estem jugant amb aixó?		Res: **si**
	[...] **el del Joan per exemple feia aixó?**[to the researcher]		
			Res: **No no això ho ha fet ara**
		S'ha trencat	
	I com fa que mengi, es que nosaltres [...] i no fa res		
	No [...] amb nosaltres		
		Te el coll tort	
7			[the researcher and the Fac talk]
360-420			[Res: se l'emporta]
	[...] [very softly]		
		[...] [molt fluixet]	
	[...] [very softly]		
	¡Te Maria, te! ¡come! [pretend to give her a leaf]		
	Quieres un espejo? [puts a ID card on her face]		
	[...]		
8		**[...]**	
420-480			[the researcehr come back with the Pleo] Res: **No li forceu el coll**
9		**Vale vale**	
480- 540			
			Mouth Full
	I si se lo pones aquí ¿que?		
	Dale algo		
	No menja		
10			
540-600	**[...]**		
		[...] [very softly]	
	Es que no menja		
	Que fa?		
		Pero ¿com es suposa que s'ha de fer això?	
			Mouth Full
	Es que no menja, no fa res!! [a la Fac:]		
		Pero ¿què se suposa que ha de fer això?	
			Fac:: **A lo millor no te gana**
11			*Sleep*
600-660	**I ara es posa a dormir**		
			Fac: ON
		Se ha muerto	
	¿Ens estas gravant? [a la Fac:]		*Wakes*
12			Fac: **Si**
660-720		**¡!Qué!!**	
	Ens está gravant		
		[es posa d'esquena a la camara]	
	Pero que fa?		
		Qué es esto?	
	Ah! que vol jugar		
	Mira		
		Porque no te gana	

	Y si le enseñas esto		
			Mouth Full
			Sleep
	¿Le has dado la del sueño?		
	¡Oyee! ¡Despierta despierta!		
		Pero ¿com es desperta aquest bicho?	
	A tots els has gravat? [a la Fac:]		
			Fac: **Què**
	A tots els has gravat?		
		Com es desperta aquest bicho?	
	I com fa que mengi, es que... tots diuen menja menja i a nosaltres no ens fa res de cas		
			Fac **No se [...]**
	I si li dones aqui. Dona-li aqui a aquest botó		
12		**No no no**	
720-780		**[...] no se despierta**	
			Wakes
	Que le has *dao* ahora se vuelve a dormir!		
	[...]		
		No se	
	Gírate Maria, Gírate Maria		
	Maria que te gires		
12	**I això que es**		
780-840	**Deja... que lo cuido**		
	Le he hecho dormir		
	***Pera pera pera* ya lo tengo**		
	No hace caso...		
		Esto es [...]	
	¡!!Espera!!!!!		
		Dale este	
	Que no!		
			Mouth Full
	[...]		
	Déjalo no le quites! Que le he [xxx] comer		
	¿Por qué dice que traga todo el mundo si escupe?		
13		**Dale la de cantar**	
840-920			Fac: **Vale ja s'ha acabat l'estona de joc**
		Por fin!	

[i] In italics Pleo's behaviour codes.
Text inside square brackets accounts for nonverbal behaviour or contextual information.
[ii] Abbreviations are as follows: Fac = Test facilitator; Res=Researcher
[...] = Verbal utterances not understood
Highlighted in yellow, the *Dyadic Pattern* episodes.

Appendix C
Field Researchers' Reports Analyses

In this appendix, we present the summary of the opinions of researchers gathered in a structured survey at the end of the field work. The first table contents the open questions of the survey.

The textual researchers' opinions are classified according to the model elaborated in Chapter 3 in three Tables: First Impression and Interaction, Usage/Adoption and Appropriation

Questions addressed to researchers

Topics	Items
Children	Pleo behaviors that are nice (to all or per age groups etc)
	Pleo behaviors that annoy / irritate. To whom ? Why? Situation.
	Age range observed minimum and maximum ages and more frequent.
	Have you observed behavior differences between boys and girls?
	Children with disorders or observable limitations (mobility deficits, intellectual). Specific behaviors with Pleo? Some kind of patient who could benefit most in particular?
	Conduct with physical contact with Pleo, rare and common behaviors observed.
	Approach to Pleo, if Pleo is in the ground do they approach? Are there children who do not play in the whole episode? Situation?
	List of rejection or fear behaviors. Location (the child was in bed, he offered to take her to that, the adults cheered etc.)
	Behaviors of abusing Pleo (such as animal Pleo) and misuse (Pleo apparatus as fragile)
Adults	Attitude of parents / mothers and families. More frequent comments. Direct interaction with Pleo observed with adults. Behaviors facilitating interaction and motivation of children.
	Attitude of volunteers.
	Attitude and behavior of nurses towards/with Pleo as a support activity. Compatibility with their job? Complementarity, see it as a resource that can be useful? Any comments or suggestions appreciative? Moments or situations where it is appropriate?
Services / spaces / situations	Of all the situations in which we have made comments on what you think the Pleo fit most and why? What you find entail more difficulties or believe they are less appropriate?
	According to your experience, do you think it would be interesting to propose services in outpatient surgery (pre-operative time and post operation time before discharge); blood tests, emergencies, other tests (X-rays), other treatments (radiotherapy, chemotherapy).
Other	Major limitations of Pleo in different situations
	Problems to solve (technical or otherwise). Situations to avoid.
	Do you discard some kind of child / or situation in the intervention?
	What could make Pleo to engage more children?
	Ideal situation in which the support of Pleo could be maximally effective.
	Do you think that a long-term company say over a week- could keep children interest and deploy role as a pet? Under what conditions?
	Regarding other resources for hospital quality of life (pallapupes, workshops, dogs) what is the added value of this intervention?

Table C_1 First Impression and Interaction

Category	Subcategories	Excerpts
First Impression	**Attraction**	**Wonder/ Curiosity/Interest** **Children** – En general, als nens no els hi fa por el Pleo i primer acostumen a acostar la mà per tocar-lo una mica. Al veure com reacciona i al constatar que no fa res, ràpidament agafen confiança i l'acaricien, agafen i toquen per tot arreu. La conducta més habitual és la de curiositat i per tant, de voler-lo tocar. La més poc habitual és la de tenir-hi por [28] – Además cuando los niños le tienen en su abrazo y el se mueve de manera cariñosa y afectuosa, apretandose al cuerpo del niño.] [1] **Parents** – Els comentaris més freqüents són del tipus: "quina passada!", "que xulo", "fa de tot"... ["es mejor que un perro", "parecen de verdad" [parents] [5] – L'actitud dels pares ha estat excel·lent, fins al punt que en alguns casos mostraven més interès que els propis nens. La majoria fan fotos al seu fill amb el Pleo. Els comentaris i preguntes més habituals han sigut: "Es poden comprar?" "On es pot comprar?", "Com es diu?", "Quin preu tenen?", "Com es diu l'empresa que el fabrica?", "Quina passada!", "Està molt ben aconseguit!", "Caram, fa moltes coses!", "Què més pot fer?", "Al meu fill li encanten els dinosaures!", "Quan ho expliqui a fulanito, fliparà!"... [29]
	Caution/ Rejection	**Fear** – [*s'acosten espontaneament?]* Claro que sí. Aunque hay niños que tienen miedo a tocarle, seguro que lo hacen una vez y rapidamente con la facilitación de un padre o de un voluntario. Había una chica, Marai, de 1 año que estuvo observando el PLEO por mucho tiempo y estuvo jugando a nuestro lado, pero negando de tocarle porque tuvo miedo. Pero eso no excluye la interacción porque me utilizo como mediador dando a mi varias veces la oja de comer para que yo la dé al dino.[3] – El 28/01/2014 la Nara (2 anys oncologia) té por del PLEO i els adults l'animen que el toqui però ella no vol. Finalment l'Arnau (cinc anys) li ensenya com l'ha de tractar i les coses que hi pot fer i la nena perd la por. .[3] – El 30/01/2014, en Marco (cinc anys, oncologia), un nen que tenia els trets d'un menut amb síndrome de Down no parava de dir-li a l'àvia que el PLEO l'espantava i això que aquesta insistia per tal que hi jugués. Em va semblar que els sorolls del PLEO era allò que més l'espantava. .[3] – El 24/02/2014, en Nil (un any, oncologia), es va espantar perquè la seva mare li va dir que el PLEO l'havia mossegat i es va espantar [4]

Category	Subcategories	Excerpts
		– La Isha (13 anys, oncologia), també li espanten una mica els sorolls del PLEO sobretot al principi o que la mossegui [4] – El 20/02/2014, l'Osama (16 anys, oncologia), tot i que li agrada molt el PLEO i s'ho passa pipa, no perd la por que el dinosaure el mossegui durant tota l'estona. [4] – Además, la mayoría de los niños de 2 años han tenido mucho miedo en el acercamiento principal. Para superarlo les ayudo observar otros jugar con el dino, o acercarle con la presencia de un adulto y hacer el adulto tocarle primero.[4] – Sols hi ha hagut una vegada en que un nen li hagi fet tanta por el Pleo que, malgrat intentar-lo convèncer, finalment no hagi volgut ni acariciar-lo [28] – Situacions inicials de rebuig i de por, malgrat ser les menys habituals, sí que n'hi ha hagut. Sempre han estat provocades pel fet d'atansar el Pleo al nen, mai pel fet que el nen, jugant amb el Pleo, s'hagi espantat degut a alguna conducta del dinosaure. En la majoria casos, s'ha donat en nens petits (5-6 anys o menys) i han acabat perdent la por al cap d'una estona [28]
		Shame – [Habían algunos niños que rechazaron el PLEO desde el principio con la excusa de que tienen perro ya y eso no les interesa. Otros, aunque evidentemente interesados, rechazaron el PLEO porque es "de niño" y no encaja con su edad (más de 13 años) .[4] – A partir d'una certa edat (9-10 anys, aproximadament), als nens els hi fa més vergonya tenir certs tipus d'interacció amb el Pleo (postura bebè en braços, per exemple) [27]
		Rejection other – Torno a esmentar que el 03/02/2014 en Fancisco (quatre anys, oncologia). No només no hi volia jugar, sinó que si veia que eren prop d'on era ell, s'aixecava i els allunyava rebotint-los i els mirava malament.[3] – El 12/02/2014, la Sònia (10 anys, planta set) a qui la mare va fer sortir fora de l'habitació empenyent la cadira de rodes que necessita la nena perquè no pot caminar, per tal que veiés els dinosaures (la Gemma i jo érem al passadís jugant amb d'altres nens), no només no va fer ni cas al PLEO que li vaig col.locar a la falda sinó que no parlava amb mi i a més a més li va dir a la mare que la dugués dins del dormitori una altra vegada.[4] – El 27/02/2014, la Cristina (7 anys, oncologia) no mostra cap mena d'interès pel PLEO, de fet em fa pensar amb la Sònia de la setena planta; tenia el dinosaure als peus i no va fer cap gest per a aproximar-s'hi ni per a tocar-lo, i no la vam poder convèncer ni jo ni un voluntari per a que hi jugués. També li va demanar a la mare que volia tornar a l'habitació; fins i tot quan la seva companya d'habitació tenia un parell de PLEOS al llit ella ni se'ls mirava .[4]

Category	Subcategories	Excerpts
		– Sols hi ha hagut un cas en que un nen no va voler tocar-lo en cap moment. [28]
		Strategies – Entre d’altres conductes facilitadores jo destacaria el fet que si el nen es mostra poruc els pares el calmen i l'inciten a la interacció [5] – La forma en que el nen s’aproxima al Pleo sovint té a veure amb l’edat. Amb nens molt petits, és millor acostar-los el Pleo mantenint-lo entre els braços o les mans, i a una certa distància. És aleshores quan normalment fan el gest d’acostar-se per acariciar-lo. Normalment, com més ràpidament s’acosten per tocar-lo és quan està al terra. Amb nens més grans, acostuma a ser millor deixar el Pleo al terra i oferir-los que l’acariciïn. [28] – [...] i han acabat perdent la por al cap d’una estona, més o menys temps en funció de la col·laboració els pares (agafant-lo ells i motivant al fill) i/o voluntaris. [28] – D’entrada no descartaria cap tipus de nen/a sense una valoració personal de la situació o un primer intent d’intervenció. En cas de detectar una actitud agressiva, que posés en perill la integritat estructural del Pleo com a robot, potser sí que optaria per no emprar el Pleo d’inici o motivar una interacció directe amb ell. [31]
Interactive practice	**Substantial contact**	**Patterns /Cuddle** – Cuando parece a coresponder a los estimulos del ambiente. Por ejemplo, si un niño le llama y el PLEO gira o cuando la acarician y se pone contento. El hecho de que los niños pueden ver si esta contento desde la manera en la cual mueve su cola, añade a la sensación de interacción – Además cuando los niños le tienen en su abrazo y el se mueve de manera cariñosa y afectuosa, apretandose al cuerpo del niño.] – Allò més habitual és que els nens els abracin, se'ls posin damunt del pit i els acaronin com si fossin cadells. També els fan petons sovint[3] – En la parte de conductas raras pondría que los niños se tumban con el PLEO en su abrazo y se ponen a “dormir” juntos.[3] – La conducta natural que fa més gràcia és amb la que s’arrauleix quan l’agafes com un bebè. La forma amb la qual demana el menjar, també atrau molt. – Además cuando los niños le tienen en su abrazo y el se mueve de manera cariñosa y afectuosa, apretandose al cuerpo del niño.] [1]

Category	Subcategories	Excerpts
	Physical contact	– Especialmente he estado con más de 4 niños con parálisis cerebral y he visto que la verdad les estimula y les motiva a intentar y hacer muchos esfuerzos de mover la mano para tocar el dino o de hablar a decirle “hola”.[2] – Es habitual también, que le cogen por la cola o intentan a meterle cosas en la boca (ojas de comer o otros objetos).[3]
	Feed	Que s'adormi, que s'enfadi i que mengi; de les tres conductes potser destacaria com a més apreciada el fet que el PLEO s'adorm, també fer-lo menjar la fulla verda enganyant-lo amb la canya de sucre [1]
	Other	Una de les coses que crec que més desconcerta (més que no pas molestar o irritar) en el comportament del Pleo, és la forma verbal que té el Pleo de comunicar-se. Sovint, encara que l’estiguis acariciant o donant de menjar, emet uns sons que semblen de descontentament [27]
	Mistreat/ Misuse	– Obrir-li la boca per tal que mengi sí o sí, és una conducta que he observat repetides vegades i que al meu parer és un maltractament del PLEO com a animal, o fins i tot clavar-li algun cop perquè no fa el que el nen vol. També inclouria el fet de posar els dits als ulls, posar-los de cap per amunt, agafar-los de la cua per tal que s'enfadin [4] – Com a conductes de maltractament, destacaria la d’agafar-lo pel coll o per la cua i la d’obrir-li la boca a la força. També, quan els nens són petits tenen tendència a posar-li els dits als ulls. Com a conductes de mal ús, destacaria la que es donava sovint a les zones de joc de consultes externes: tants nens i tots volent tenir al Pleo, provocava que a vegades l’estiressin o rebés cops. [28]

Table C-2 Usage/Adoption

Category	Subcategories	Excerpts
Attachment	**Individualization Personalization**	i també nens que et demanen pel nom d'un PLEO en concret, o et pregunten com es diuen els que portes aquell dia.[7]
	Soliciting	– Només veure el PLEO ja recorden que l'havien vist abans i la majoria han demanat tornar-lo a veure, alguns nens fins i tot els han buscat. [7] – Hi ha nens que et pregunten quan tornarem [7] – Els nens que han tornat a l'hospital i ja havien vist al Pleo anteriorment, venen a veure'l si se'l troben, i inclús, més d'un cop, algun voluntari ens ha comentat que el nen havia hagut de marxar però que havia preguntat pel Pleo. De fet, en una ocasió, una mare ha anat a preguntar directament al despatx dels voluntaris per saber on estàvem i poder venir a veure'ns, perquè la seva filla tenia moltes ganes de tornar a veure al Pleo[30]
	Missing/ Proximity Seeking/ Sorry for separation/	– Hay también niños que no quieren que les quiten los PLEOs y preguntan si les veran de nuevo y cuando.] [7] – [*coses que no faria*] Deixar-li molt temps el PLEO a un nen que estigui molt deprimit, perquè després caldrà treure-li, i això ho dic sense saber si aquest serà l'efecte de la retirada, però penso que potser el podria fer empitjorar.[9]
	Memories/story	– [s'acosten espontaneament?] N'hi ha que sí, però gairebé sempre que s'hi acosten sense que tu els diguis res, és perquè ja hi han jugat un altre dia i saben que és una cosa que poden fer.[3] – També et demanen poder donar-los menjar si no has pensat a treure les fulles. Una altra cosa que fan es repetir les coses que ja saben fer am el PLEO: adormir-lo, acariciar-lo, donar-li menjar, provar que jugui amb la pedra....[7] – niños que la primera vez estuveron más tímidos y no han interactuado mucho, mientras que la vez siguiente se aprovecharon más. He encontrado una niña por consultas que me comento que nos había visto el día anterior, pero no nos acerco. Además, había un chico, Joel, que nos vi por arcoiris y rechazo la idea de jugar, mientras que el día siguiente por la ciberaula si que mostro mucho más interese.[7] – De tota manera penso que el PLEO és més que una joguina i per aquest motiu crec que és interessant que el nen que hi interactuï ho pugui fer ell sol i així podrà realment beneficiar-se de totes les aplicacions que tenen aquests robots, si té massa nens al costat que contínuament interrompen la seva interacció, mai acabarà d'entendre o aprendre com funciona i això farà que se'l miri com si fos un simple ninot amb piles. Parlo sobretot de les primeres aproximacions dels nens als PLEOS, un cop ja han entès de què va, ells mateixos poden fer "d'educadors [7] uniqueness

Category	Subcategories	Excerpts
		– En aquests casos de retrobada (d'una o més vegades), l'actitud del nen és molt més confiada d'entrada i enseguida l'agafen o demanen per donar-li de menjar o jugar amb la corda i la pedra [30]
	Affection	
Collective gaming	**Families**	**Enjoyment** – També els fan moltes fotos i molts vídeos perquè volen compartir l'experiència amb d'altres familiars o amics, i també perquè volen tenir un record d'aquells moments[5]. – Respecte a l'ajuda de cara a presentar el Pleo als fills, cal dir que en general també ha estat excel·lent, ja que, com que els propis pares volien que el nen acariciés el Pleo, s'han mostrat totalment predisposats a agafar el Pleo i atansar-lo al fill. Molts pares, també han participat del fet de donar de menjar, acariciar el Pleo, etc. per tal que el nen mantingués l'interès passada una estona o donada una certa apatia del Pleo.[29]
		Facilitating – L'actitud dels pares és molt oberta a que els nens juguin amb el PLEO, contínuament els inciten a tocar-los, a fer-los petons, a tractar-los bé. [...]Entre d'altres conductes facilitadores jo destacaria el fet que si el nen es mostra poruc els pares el calmen i l'inciten a la interacció, i també que repeteixin allò que diuen els nens en forma de pregunta per mostrar que hi estan interessats, per exemple si el nen diu "mira com menja" ells contesten coses com ara "ah sí menja?", i hi ha progenitors que fan sentir especial al nen dient-li coses com ara "però si et coneix!". També hi ha molts pares que juguen amb el PLEO conjuntament amb el nen. En tot cas, no n'hi ha cap que es quedi arraconat sense fer res o callat, n'hi ha que fins i tot també proven de fer amb el dinosaure les mateixes coses que fan els fills, o bé perquè aquest els ho demana, o bé de manera voluntària.[5]
	Volunteers	
	Nurses/Staff	– Un infermer va fer dormir el PLEO, li va donar menjar, hi va jugar.... i tot plegat perquè a l'entrar a l'habitació de la Mireia (18 anys, oncologia) es va quedar parat perquè no n'havia vist mai cap i els pares de la noia van insistir per a que provés de jugar-hi. [6]

Category	Subcategories	Excerpts
Disinterest		– El hecho que algunos niños se aburren tiene que ver mucho con el hecho de que ellos esperan que este dino tiene que hacer cosas guays. [8] – [Cuando estan aún “pequeños” no pueden mostrar una gama amplia de conductas y eso quizás aburre los niños. Además, aún cuando se crecen no “toman la iniciativa” de empezar a caminar o girar a sonidos, algo que les haría mucho más parecidos a seres vivos.] [9]
Maintenance		– Además hacer la construcción de los PLEO más duradera- me ha pasado que de repente le pasa un choque por el cuello y se queda así y se recupera dentro de rato.[9] – Les bateries duren poc. Són molt delicats i si els utilitzen nens petits queden tronats molt ràpidament. Sembla que l'ambient interfereix massa en els sensors auditius. Si reculen enrere cauen si estan en un lloc alt.[9] – Pell: es desgasta i es desenganxa. Poca duració de la bateria. Cal preveure de portar-ne més d’una per cada Pleo. Articulació del coll delicada. Poca qualitat dels sensors de so (auditius). Si hi ha molt de soroll a l’ambient costa que el Pleo entengui ordres. Fragilitat davant de caigudes des de llocs elevats (llits, cadira, etc.). [30]

Table C_3 Appropriation

Category	Subcategories	Excerpts
Health related outcomes	**Children**	**Spetial Needs** – Hi ha una nena, la Mariona (5 anys, oncologia) que té dificultats amb la parla i el fet que jo imités els sorolls del PLEO la feia riure sempre; a més a més la nena s'esforçava a parlar perquè volia explicar als pares les coses que feia amb el dinosaure. En aquest sentit, si aquesta interacció els fa comunicar-se verbalment més sovint, penso que pot ser bo per a ells[2] – Una altra cosa que crec que pot ajudar, és quan hi ha nens amb problemes de mobilitat, perquè com que volen fer coses amb el PLEO, mouen les extremitats i segurament això és un exercici que els beneficia.[2] – Especialmente he estado con más de 4 niños con parálisis cerebral y he visto que la verdad les estimula y les motiva a intentar y hacer muchos esfuerzos de mover la mano para tocar el dino o de hablar a decirle “hola”.[2] – Además, podría facilitar niños con dificuldades de concentración (como Acier, 5 años).] – La motivació que sovint genera el Pleo, es pot canalitzar en pacients amb problemes de mobilitat i/o en procés de rehabilitació, i amb els següents objectius: • Fomentar l’ús de la motricitat fina: donar de menjar, jugar a l’estira la pedra... • Fomentar l’ús de la motricitat gruixuda: acariciar el Pleo. • Ajudar en la fisioteràpia, com a “gos manta tipus B” (modalitat d’ús de gos en teràpies, normalment de fisioteràpia, patentat pel CTAC. En aquesta modalitat, el gos està deixant-se abraçar o molt a la vora de l’usuari, i per això normalment s’empren gossos petits) [27] També es pot emprar el Pleo en teràpies de l’àmbit cognitiu, tot creant activitats i dinàmiques en les que l’usuari hagi d’interactuar amb el Pleo i s’aprofiti per treballar objectius emocionals, socials, cognitius... – [...]la [conversa] que vaig mantenir amb dos metgesses especialitzades en Implants Coclears, les quals van veure ràpidament el potencial d’aplicació del Pleo per a seves teràpies.[29] – també voldria destacar el de la Dra. Amaia Hervás, la qual va mostrar molt d’interès inicial en la Robòtica Social i les possibilitats d’aplicació en teràpies amb nens amb TEA. [30]

Category	Subcategories	Excerpts
	Families	**Distract/ Entairtain/ Cheer-up** Si hay un momento en el cual los niños no hacen caso al PLEO, los padres se aprovechan para explorar la criatura ellos mismos. Muchas veces he dejado un PLEO con una familia y cuando volví el niño estuvo ocupado con algo otro, mientras que los padres estuveron jugando con el dino (acariciandole o teniendole en su abrazo y dandole comida)!][5]
Compatibility /value	**Volunteers**	– Els voluntaris sovint hi juguen també, de fet són allà per a jugar amb els nens, i quan hi ha un PLEO, doncs segueixen amb la tasca. N'hi ha que també els fan fotografies i tots fan comentaris positius sobre el dinosaure, com ara que els agraden molt. Alguns d'ells s'interessen pel projecte i fan preguntes al respecte; tots ells tenen una actitud molt cordial i molt col·laborativa, inciten als nens a interactuar-hi. A més a més, arriba un moment que ells també els expliquen als nens o als pares coses sobre els PLEOS: quant valen, què fan...gairebé com si formessin part del projecte![6] – [Además, muchas veces nos dan informaciones sobre los niños (tipo de enfermedad/dificuldad, comportamiento general si conocen al niño, veces de ingresión, intereses, etc.)[6] – Han mostrat molt d'interès. Ha estat la curiosa la frase, tants cops repetida, de primera trobada entre el Pleo i un voluntari: "Ahhh, aquest és el Pleo del qual he sentit tant a parlar!!" [29]
	Nurses	– Un infermer va fer dormir el PLEO, li va donar menjar, hi va jugar.... i tot plegat perquè a l'entrar a l'habitació de la Mireia (18 anys, oncologia) es va quedar parat perquè no n'havia vist mai cap i els pares de la noia van insistir per a que provés de jugar-hi. [6] – Moltes infermeres em fan preguntes sobre els PLEOS (com ara quan valen, quines coses fan, o en què consisteix el projecte), i també n'hi ha que expliquen que les companyes els han parlat d'ells, també em demanen que vagi a les habitacions, amb la qual cosa demostren que pensen que allò és bo per als nens. Quan entren en un dormitori i es troben amb el PLEO, fan comentaris de sorpresa i de satisfacció de cara a provocar reaccions positives en els nens, coses com ara "que xulo no?" . De vegades també demanen d'agafar-los. [6] – El personal d'infermeria tenia una actitud positiva i col·laboradora però no es va implicar amb els PLEOS, jo penso que sobretot perquè estaven treballant, i també perquè a l'hora de distreure els nens, deuen estar acostumats a que

Category	Subcategories	Excerpts
		siguin els voluntaris qui facin aquesta tasca. Això sí, com he dit abans, de vegades feien de missatgers entre nosaltres i els nens que no podien sortir de l'habitació (sospito que fins i tot per iniciativa pròpia).[6] – Només m'he trobat amb un moment en què alguns membres del personal d'infermeria van considerar els PLEOS com a una cosa inoportuna, i va ser el 12/02/2014 quan érem amb la Gemma al terra del passadís de la setena planta jugant amb uns quants nens, i tot d'una van venir unes infermeres a dir-nos que allà no hi podíem estar perquè no era el millor lloc per als nens. Dic que no els van considerar oportuns perquè no ens van oferir l'alternativa de quedar-nos amb els nens en alguna altra sala de la planta, o que anéssim a les habitacions.[7] – No he tingut pràcticament cap interacció amb infermeria, ja que a consultes externes i sala Arc Iris, no n'hi acostumava a haver. La poca interacció que he tingut ha estat pels passadissos i durant el "passa-habitacions" per promocionar el taller dels Pleos. Sempre he notat una actitud receptiva, curiosa i d'interès, respecte el Pleo[29+
	Other staff	– Solo una vez había una voluntaria del projecto de los perros que nos hizo completamente nada de caso en cuanto a jugar con los niños con las dos mascotas[6] – [...] sí que puc comentar l'interès rebut per part d'alguns metges. En general ha estat molt bo. Com que he aprofitat el moment del cafè per portar el Pleo al bar de l'hospital, allà m'han preguntat molt i han sorgit converses molt interessants. Com per exemple, la que vaig mantenir amb dos metgesses especialitzades en Implants Coclears, les quals van veure ràpidament el potencial d'aplicació del Pleo per a seves teràpies.[29]
	Facilities/Activities	– [En el meu caso, que he estado por arcoiris y consultas externas, diría que por los dos lados hay tanto ventajas como inconvenientes. Por arcoiris, hay la posibilidad por una interacción más **personalizada**, porque hay menos niños a la vez. La necesidad de distracción es alta tanto por los niños como por los padres. Pero en esta aula, las conductas por parte de los niños parecen de demandar que los PLEOs hagan cosas divertidas y no se fijan en la relación que podrían desarrollar con el dino. Además, los niños en esta aula no pueden ni beber ni comer y eso les hace aburrirse o irritarse más facilmente, especialmente cuando les piden dar a los PLEOs comida ("si tengo que meter la oja en una boca, la metiré en la mía!"). [8] – Por otro lado, por consultas externas hay muchos más niños y muchas veces hay más demanda que oferta. Pero los niños ahí se sienten más "libres" en elegir de acercarnos o no y además pueden comprometerse más facilmente en tipos de interacción que incluyen a otros niños también- "jugamos **todos juntos**". Aquí también hay la necesidad de distracción, porque, aunque su situación no es igual grave, muchos de los niños quedan toda la mañana visitando medicos y tienen que volver al ambiente hospitalario varias veces al mes. [8]

Category	Subcategories	Excerpts
		– En ninguno de los casos hay la posibilidad de una interacción con el PLEO continua, porque en su mayoría no se trata de niños ingresados, y eso es un inconveniente importante, porque el tipo de cuidado que ofrece el PLEO se situa en la relación de afecto que uno establece con el [8] – [Claro que sí. Diría que los PLEOs podrían ser muy útiles en todas las facetas del ambiente hospitalario, tanto en interacciones instantaneas (urgencias, pruebas de sangre, radiografias) como en interacciones a largo plazo y más continuas (cirurgia, tratamientos). Aunque en el primer caso la interacción se basa en el efecto de la novedad, mientras que en el otro se basa en la relación que se desenvolupa entre PLEO y niño, los dos pueden benecifiar el niño y facilitar su estancia por el hospital.] [8] – [avantatges]Que sempre poden estar a les habitacions, sigui quina sigui la malaltia del nen, perquè no embruten, i en principi no contaminen. Hi ha l'opció també que el tinguin durant dies, i això suposa que no hi hagi límits d'horaris i que estiguin disponibles sempre que el nen els necessiti. – [Un PLEO se hace de una combinación muy interesante de las otras alternativas. Con un comportamiento parecido a un perro, el PLEO inspira al niño desarrollar una relación con el y, en contraste con el perro, con el PLEO pueden estar más rato porqué si se cansa le cambiamos la bateria. Además, podemos controlar el bienestar de los PLEOs, mientras que los animales se estresan después de un cierto rato. Tanto la disponibilidad de los PLEOs como el hecho que pueden compartirlo y jugar con otros niños todos juntos, hace del PLEO una combinación bastante completa. Además, en la interacción con el PLEO los niños tienen un papel mucho más activo, porque el bienestar del PLEO depende de la manera en la cual le tratan ellos mismos y los niños pueden enseñar cosas al PLEO y experimentar con el. Y esta “libertad” de intervenir y inventar la forma de la relación no la ofrecen los otros recursos.] – Les situacions on crec que encaixen més és a les visites a les habitacions (malgrat que inicialment no ho teníem previst) i sala de jocs d’oncologia i a les sales ArcIris, ja que l’ambient acostuma a ser més tranquil, el número de nens molt menor i la qualitat de la interacció pot ser millor. A les plantes de consultes externes i a la CyberAula és on crec que la qualitat de la interacció ha estat més baixa ja que, a part que ja tenen altres estímuls, també hi ha molts més nens i això a vegades comporta petits conflictes o interaccions molt curtes per tal que tots el puguin veure i estar amb ell. El número de nens és molt important, si hi ha més de 3-4 nens, va molt bé tenir un o dos Pleo’s més. [30] – De les actuacions fetes durant aquest treball de camp, destacaria la d’acompanyament a l’habitació [31]
Recommendations		– Caminar més. Seguir a qui el cridi pel nom com si fos una mascota.

Category	Subcategories	Excerpts
		Dirigir l'atenció automàticament amb el coll i el cap a qui li parli.[10] – [Totalment de acuerdo. Y además, podría hacer más sonidos y comprometerse más facilmente en comportamientos de juego.] .[10] – Bateries: evitar sols portar una bateria. La duració de la bateria (encara que estigui totalment carregada) també és variable, ja que depèn de lo actiu que estigui el Pleo.Pell: portar la roba del Pleo i posar-li de tant en tant. Tenir cura d'enganxar-la a la mínima que es veu que es desenganxi en algun punt. Soroll ambiental: procurar estar en llocs on es pugui fer una mica de silenci si es vol més fiabilitat a l'hora que el Pleo entengui el seu nom o executi una habilitat. [31] – Fer més fàcil i ràpid el procés d'ensenyar-li i fer-li fer habilitats, i que no depengués tant del soroll ambiental o, directament, dels sensors auditius. Respecte al comportament que ja té, no sé posicionar-me en si caldria modificar-lo perquè sigui més "perrito faldero" o no, ja que depèn de com, una actitud de cert distanciament pot motivar la voluntat d'interacció del nen. El que sí que seria convenient és que sàpiga totes les habilitats i sigui fàcil fer-li fer, és a dir, que sempre que li cridis l'atenció (tocar les dos galtes a la vegada) et faci cas. Això es pot aconseguir si es modifica (reprogramant) l'ADN del Pleo, més concretament, el nivell d'Obediència. El que a la llarga també seria molt interessant és que el Pleo pugui, de forma automàtica, canviar la seva conducta en funció de la interacció que percebi de l'usuari que estigui "jugant" amb ell. [31] – Com a noves situacions: • les relacionades amb oncologia (radioteràpia, quimioteràpia...). • de resultes del treball de camp i valorant les converses amb metges i resta de personal de l'hospital, una molt bona situació seria en teràpies individuals o grupals de poca gent, amb activitats i dinàmiques prèviament pensades i dissenyades per tenir al Pleo com a figura central però per treballar altres aspectes.[32] – [qué aportaria respecte altres recursos] • La higiene i adaptabilitat a diferents ambients i zones hospitalàries. • L'acompanyament de llarga durada. • Complement puntual ideal per a aquests altres recursos de vida hospitalària