Full-body Interaction and Autism: Design, Development and Evaluation of Experiences as Tools for Intervention on Motivation and Social Initiation for ASD Children

Joan Mora Guiard

TESI DOCTORAL UPF / 2016

Director de la tesi

Prof. Narcís Parés Burguès,

Department of Information and Communication Technologies

Universitat Pompeu Fabra Barcelona

For a world where HCI is at the service of quality and not quantity.

Acknowledgements

I would like to first thank my supervisor, Narcís Parés. Narcís has been a mentor since I did my final bachelor project in 2008. He gave me the chance to apply my Computer Science knowledge to people with special needs, which has been always the motivational drive of my work. Since we started to work together, he has shown more patience and dedication with me and my PhD than I could have ever imagined. Narcís has always been really supportive and I would like to thank him for his guidance through all these years. Although I finish a period, I hope one day we will work together again.

I would also like to thank Núria Monné. Núria, has mostrat sempre un suport i una paciència infinita amb mi, no sols des que va comenar aquesta aventura, sinó des de la que compartim junts. Sense els teu recolzament, concells, ajuda i empenta mai hagués arribat fins on ho he fet. Has estat un mirall de superació en el que volia reflectir-me.

I would like to thank my family, both my parents and my sister. They have always been an inspiration to become a better person and professional. I can only say how lucky I am to be from the same blood lineage my superheroes are.

Thanks to my laboratory colleagues. Pascal, your humor, knowledge and guidance have been fundamental for me to be able to finish this PhD. You have helped me to grow as a researcher and interaction designer. Laura, your huge intelligence, design knowledge and energies have been also key for me being able to do all this work, one that I can feel proud of. Marie, thanks for your feedback and help when needed. Finally, thanks to Ciera for helping me in the last steps of my research, I am sure you will bring the research I have started from its beginnings to a new level.

I want to thank all the psychologists, caregivers, families and, specially, children who have contributed to this research as experts, designers and users.

I would also like to thank the FundacióTekhnikós, European Comission and Fundació La Caixa for financing and supporting the projects presented in this article.

Abstract

This thesis focuses on the design, development and evaluation of a series of full-body interaction experiences as tools for intervention on motivation and social initiation for children with Autism. Autism Spectrum Disorders are characterized by challenges in the social communication domain which might translate into difficulties in forming and maintaining relationships with peers. Thus, it is necessary to provide support tools for motivating the learning and use of social behaviors and countering social fragmentation. We developed three systems to explore the characteristics and limitations of the full-body interaction medium for the development of such tools.

This thesis analyzes the characteristics of full-body interaction technologies by focusing on different physical settings, and different interaction design approaches. We have focused our research on motivation, through promoting engagement and exploration attitudes, and social behaviors, by fostering social initiation and collaboration in multi-user environments.

This thesis is a first step to design full-body interaction systems as intervention tools for promoting motivation and social behaviors. We present three approaches by first defining each project's requirements and goals. Then we select a physical interface and explain how we use it for designing the interactions to achieve our goals. We follow with an explanation on how the content for the system was designed. Then, we explain the development process for each system. Finally, we explain the experimental evaluation of each one of the three projects. We follow each project explanation with a summary of individual takewayas of each project, which then are gathered in an analysis table. We provide interaction design guidelines for designing full-body interaction experiences aimed at promoting engagement and social initiation. We finish with the limitations and future work that our research leads to.

Resum

Aquesta tesis es focalitza en el disseny, desenvolupament i avaluaci d'una srie d'experincies d'interacci a cos sencer com a eines d'intervenci en motivaci i inicialitzaci social en nens amb Autisme. El Trastorn de l'Espectre Autista es caracteritza per dificultats en l'mbit de la socialitzaci i comunicaci, que es pot traduir en dificultats per crear i mantenir relacions amb els companys. Per tant, s necessari de proveir eines de suport per a motivar l'aprenentatge i s de conductes socials i contrarestar la fragmentaci social. Hem desenvolupat tres sistemes per a explorar les caracterstiques i limitacions dels mitjans d'interacci a cos sencer per al desenvolupament d'aquestes eines.

Aquesta tesis analitza les caracterstiques de les tecnologies d'interacci a cos sencer a travs de focalitzar-se en diferents configuracions fsiques, i diferents aproximacions de disseny d'interacci. Hem focalitzat la nostra investigaci en la motivaci, a travs del comproms i actituds exploradores, i actituds socials, a travs d'encoratjar la iniciaci social i la collaboraci en entorns multi usuari.

Aquesta tesis s un primer pas en el disseny de sistemes d'interacci a cos sencer com a eines d'intervenci per a promoure la motivaci i conductes socials. Presentem tres aproximacions on primer expliquem els objectius i els requeriments de cada projecte. Desprs expliquem la selecci de la interfcie fsica i expliquem com l'hem utilitzada per al disseny de les interaccions necessries per a assolir els nostres objectius. Continuem l'explicaci del disseny explicant com s'ha dissenyat el contingut del sistema. Tot seguit, expliquem

com ha estat el procs de desenvolupament per a cada projecte. Finalment, expliquem el procs d'avaluaci experimental per cada un dels tres sistemes. Seguim l'explicaci dels tres projectes amb una recapitulaci de les diferents conclusions de cada un dels projectes, les quals recopilem en unes taules d'anlisis. Provem d'una srie de guies per al disseny d'interacci per a sistemes d'interacci a cos sencer per a promoure la motivaci i la inicialitzaci social. Acabem amb les limitacions i treball futur resultants de la nostra feina.

Contents

Abstract **vii**

Resum **ix**

Contents **xi**

List of Figures **xv**

List of Tables **xvii**

1 Introduction **1**

1.1 Goals 3

1.2 Contributions 5

1.2.1 Publications 7

1.3 Thesis structure 11

2 State of the Art **13**

2.1 Autism 14

2.1.1 Challenges 16

2.1.2 Interventions 18

2.2 Embodied Cognition 23

2.2.1 Currents Associated to Embodied Cognition 23

2.2.2 Embodied Interaction 25
2.3 Autism and ICT 27
2.3.1 Learning of non-social specific skills 29
2.3.2 Motivating social interaction 31
2.3.3 Learning social communication skills 33
2.4 Full-body Interaction 34
2.5 Interdisciplinary Approach 36

3 Full-body interaction for Music Therapy 39
3.1 Goals & Requirements 41
3.2 Interaction Design 42
3.3 Design & Development 44
3.4 Evaluation 47
3.4.1 Hypotheses 47
3.4.2 Experimental Design 48
3.4.3 Participants 51
3.4.4 Methods 51
3.4.5 Procedure 56
3.5 Results 58
3.6 Conclusions & Discussion 65

4 A Kinect-based game for learning social skills 67
4.1 Goals & Requirements 70
4.2 Interaction Design 76
4.3 Design & Development 77
4.3.1 Participatory Design 77
4.3.2 Final Design 82
4.4 Evaluation 87
4.4.1 Hypotheses 88
4.4.2 Experimental Design 88
4.4.3 Participants 89
4.4.4 Methods 91
4.4.5 Procedure 93

4.5 Results 94
4.5.1 Comparison of overall Social Initiation 96
4.5.2 Comparison of Specific Social Initiations 97
4.6 Conclusions & Discussion 102
4.6.1 Third-person approach 106
4.6.2 Simple initial mechanic with discrimination of stimuli 108
4.6.3 Discrimination of stimuli with and antagonist 109
4.6.4 Peephole and forcing the need to ask for help 109
4.6.5 Holding hands 110
4.6.6 Pointing to objects and the need to coordinate 111

5 Promoting collaboration and social inclusion 113

5.1 Goals & Requirements 115
5.2 Interaction Design 116
5.2.1 The physical interface 116
5.2.2 Design Strategies 117
5.3 Design & Development 125
5.3.1 Participatory Design 126
5.3.2 State diagrams for game design 126
5.3.3 Final design 127
5.4 Evaluation 130
5.4.1 Two studies 130
5.4.2 Hypotheses 130
5.4.3 Ethical validation 131
5.4.4 Experimental Design 131
5.4.5 Participants 132
5.4.6 Methods 134
5.4.7 Procedure 136
5.5 Results 137
5.5.1 Child Motivation 137
5.5.2 Socialization 140
5.5.3 Collaboration 141
5.5.4 Perception 142

5.6 Conclusions & Discussion . . . 142
5.6.1 Potentialities for therapy . . . 143
5.6.2 Possibilities for school implementation . . . 144

6 Full-body interaction analysis 149
6.1 Individual projects contributions . . . 150
6.1.1 SIIMTA . . . 150
6.1.2 Pico's Adventure . . . 152
6.1.3 Lands of Fog . . . 156
6.2 Common contributions . . . 160
6.2.1 Research goals . . . 161
6.2.2 Physical setting . . . 162
6.2.3 Interaction paradigms . . . 162
6.2.4 Interaction design . . . 163
6.2.5 Design methods . . . 164
6.2.6 Content design . . . 165
6.2.7 Assessment . . . 165
6.2.8 Procedure . . . 166
6.2.9 Results . . . 167
6.3 Suggested guidelines . . . 168

7 Conclusions 173
7.1 Limitations and Future Work . . . 175

A Appendix 179
A.1 Questionnaire Used for SIIMTA Experimental Assessment . . . 179
A.2 Video Coding Scheme for Pico's Adventure Assessment . . . 181
A.3 Lands of Fog Barcelona Questionnaires . . . 184
A.4 Lands of Fog London Questionnaires . . . 195

Bibliography 203

List of Figures

3.1 Fullaraca 40
3.2 SIIMTA visuals 45
3.3 SIIMTA playing 46
3.4 Audio logs visual operationalization 54
3.5 Silhouette videos operationalization 55
3.6 SIIMTA in El Carrilet 57
3.7 Normality test for movement density values 58
3.8 Wilks' Lambda test for movement density 59
3.9 Boxplot diagram for movement density 60
3.10 Normality test for sound logs values 60
3.11 Friedman's test for audio logs values 61
3.12 Boxplot diagram for audio logs scores 61
3.13 2 sample post-hoc test for audio logs for Session 1 62
3.14 2 sample post-hoc test for audio logs for Session 2 62
3.15 2 sample post-hoc test for audio logs for Session 3 62
3.16 2 sample post-hoc test for audio logs for Session 4 62
3.17 2 sample post-hoc test for audio logs for Session 5 63
3.18 2 sample post-hoc test for audio logs for Session 6 63
3.19 2 sample post-hoc test for audio logs for Session 7 63
3.20 2 sample post-hoc test for audio logs for Session 8 63

3.21 Friedman's test for question 3 responses 64
3.22 Boxplot diagram for question 3 responses 65

4.1 Pico's Adventure First Session 83
4.2 Pico's Adventure Second Session 85
4.3 Pico's Adventure Third Session 86
4.4 Pico's Adventure Fourth Session 87
4.5 Comparing social initiation in Pico's Adventure and free play . . 97

5.1 Lands of Fog Virtual Environment 119
5.2 Fireflies below the fog 120
5.3 Two pointers with their two creatures 122
5.4 Initial State Diagram for players 127
5.5 Scatter plot correlating answers to how much children knew their partner to if they thought they would have talked more to their partner in the playground than in the game. 145

List of Tables

4.1 Classification of general objectives, relative social skills and game mechanics for level 1 and level 2 . . . 78
4.2 Classification of general objectives, relative social skills and game mechanics for level 3 and level 4 . . . 79
4.3 Translation of treatment plan into game levels and addressed social skills . . . 79
4.4 Participatory design structure . . . 80
4.5 Experimental conditions . . . 89
4.6 Video slots for analysis . . . 92
4.7 Video pairing for comparison . . . 95
4.8 Summary overall social initiation . . . 98
4.9 Integrated requests . . . 100
4.10 Non-Integrated requests . . . 101
4.11 Integrated social commentaries . . . 103
4.12 Non-integrated social commentaries . . . 104
4.13 Game mechanics . . . 106
4.14 Game mechanics comparison . . . 107

5.1 Distance Covered during Sessions . . . 138
5.2 Number of Hunted Fireflies . . . 138
5.3 Number of Seconds Still . . . 138

5.4 Activity Level 139
5.5 Flexibility Level 139
5.6 Number of Social Initiations 140
5.7 Number of Responses by Children with ASD 140
5.8 Total Amount of Social Acts 140
5.9 Number of Virtual Elements Manipulated 142
5.10 Mean Distance between Children (cms) 142

6.1 Research goals 161
6.2 Physical setting 162
6.3 Interaction paradigms 163
6.4 Interaction design 164
6.5 Design methods 164
6.6 Content design 165
6.7 Assessment 166
6.8 Procedure 167
6.9 Results 167

Chapter 1

Introduction

In the mid 1970s, given the expansion of Information and Communication Technologies (ICT) in work environments, an interest towards understanding the potentials of how humans interact with computers started to grow (Carlisle 1976). The research focused on the interaction of humans with computers, which was born from this growing interest, is known as Human-Computer Interaction (HCI). For the Association for Computing Machinery (ACM) HCI is “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Hewett et al. 1992).

Years before the conception of this discipline of research, when the first digital computers where being created, in the field of philosophy a post-Cartesian conception of body and cognition started to grow. While Cartesian dualism views cognitive phenomena detached from the physical world, those new theories on human cognition started to account on the importance of the body, physicality and phenomena. These new theories on how cognition is mediated by the body, and it being embedded in the world, are known as Embodied Cognition (Borghi and Cimatti 2010).

Between these two apparently unrelated disciplines exists an interest to understand the capabilities of the body and situatedness as an important part of HCI. One of the pioneers on the former is Myron Krueger. With installations such as Videoplace (Krueger et al. 1985), Myron Krueger explored the interaction between human's and machines focusing on the importance of the body and movement, what he called Responsive Environments (Krueger 1977). The use of the movements and the actions as interaction means is also known as Full-body Interaction, a form of Embodied Interaction. Research has shown that this interaction paradigm approach is successful in fostering user's engagement (Bianchi-Berthouze et al. 2007) but also for the learning of concepts (Antle et al. 2009; Howison et al. 2011). Furthermore, full-body interaction systems seem to be also effective on encouraging socialization behaviors (Lindley et al. 2008).

In this PhD Thesis, given the characteristics of full-body interaction systems, we want to explore and define their potentialities for developing assistive technologies for helping children with Autism Spectrum Disorder (ASD). ASD is a neurodevelopmental disorder which is characterized by impairments in social communication abilities, and limited and repetitive interests (Diagnostic and Stathistical Manual of Mental Disorders, 5th Edition (DSM-V), Association 2013).

Our research has been focused on the design, development and evaluation of different full-body interaction systems designed for children with ASD. More precisely, during this thesis two different intervention tools were developed through different approximations to full-body interaction, both of them with the goals of engaging the user, fostering exploration, and motivating socialization and communication behaviors. This research started with a Master Thesis project which was also the design, development and evaluation of a full-body interaction experience for children with ASD based on Music Therapy principles. Thus, the following work presents three full-body interaction systems designed for children with ASD, the outcomes of their experimental analysis and some discussion and generalization for the design of new embodied interaction installations for children with ASD. All the presented research has been closely done with the collaboration of psychologists and caregivers, and children with Autism have been included as design informants through Participatory Design sessions and trials.

For this PhD Thesis our approach to ASD has been based on the definition from the DSM. During the first and second projects presented in this PhD Thesis, the 4th edition was the last one published and taken into account. For the third project, the recently published 5th edition was our reference. Our research has been always assisted and assessed by psychologists and therapists with previous experience with ASD. We are aware of the different opinions and sensibilities when talking about Autism, and in now way this work pretends to revile individuals with ASD with our terminology. The use of the word "disorder" instead of "condition", also ubiquitous in the HCI field, is merely based on the definition of the DSM.

1.1 Goals

The main goal of this thesis has been, as its title indicates, to design, develop and evaluate a series of full-body interaction experiences as tools for intervention on motivation and social initiation for children with autism. Our research has been focused towards exploring and specifying the potentialities of this media from a HCI and technological approach for the development of therapeutic and intervention systems for children with ASD geared towards promoting engagement and socialization.

As aforementioned, we have developed three different full-body interaction systems for exploring different approximations of embodied interaction for developing technology specifically for children with ASD. We designed and developed the systems to see the different affordances and potentialities different physical configurations have for this purpose. The three different approaches are:

- A large screen full-body interaction installation for music therapy called SIIMTA (Chapter 3).
- A Microsoft Kinect based videogame to promote social behaviors for the European Comission's M4ALL research project, named Pico's Adventure (Chapter 4).

- A 6 meters diameter floor projected multi-user environment for promoting socialization for the In-Autis-Tic RecerCaixa 2013 research project, called Lands of Fog (Chapter 5).

We believe it is important to clarify that these three systems do not represent all the possibilities of how full-body interaction can be implemented. We have selected these three systems on the one hand, to analyze three different approximations to full-body interaction, and on the other because we believe they were the best technological and interaction configurations to define the mediation of the experience to the user that best deals with the therapeutic goals of the three different research projects.

The potential of full-body interaction systems is based on cognitive theories that stress the relationship between physical activity and cognitive processes, known as Embodied Cognition. Embodied cognition theories emphasize the role of the body and sensorimotor activity when interacting with the physical environment in the development of cognitive processes (Wilson 2002). Embodied cognition provides the theoretical underpinnings for defining the potentials of intervention through full-body interaction systems. A deeper introduction to embodied cognition is provided in Section 2.2.2. Research shows that an increase in body movements in multiplayer settings increases the social nature of the gaming experience (Bianchi-Berthouze et al. 2007), thus making full-body interaction systems an interesting approach for social therapy and intervention.

For each system we present in this thesis we carried out an experimental evaluation to understand the strengths and weaknesses of the design and medium used. Each project has been designed for children with ASD, but focusing on different diagnostic severity subgroups and different characteristics and challenges related to ASD. Nonetheless, we have not just developed these systems for research, but actually each system was developed with the goal of having a full-body interaction system that could be ready at use by psychologists, therapists, family and caregivers. Thus, another goal for this thesis was to develop deploy-ready systems which could be used by final users in real contexts. We understand that for really assessing the potentialities of this kind of media, but also for being able to compile a set of design guidelines, it is mandatory to design and develop systems with the quality expected for products which would be used in real life. We developed the full-body interaction experiences with the quality level we thought was necessary for children to accept as professional products. Nonetheless, this products were focused for an interaction design evaluation, thus real integration in therapeutic programs is needed to fully assess their efficacy as therapy aid tools. In each chapter we will explain the meticulous process we have followed for each project. First we aimed to understand the necessities of our population and the project with the stakeholders. Second, we present for each project the technology we chose and an analysis on how it could best suit the goals of the project. Third we explain how we made use of the technology through explaining the interaction design. Finally, we will explain for each project the development process of the system and its evaluation.

The last goal of this thesis is to develop a series of design guidelines and "good practices" for future developers of full-body interaction systems for children with ASD aimed at promoting engagement and socialization.

1.2 Contributions

Our objective has been to explore and specify the potentialities of full-body interaction technologies from a HCI and technological approach to the development of therapeutic and intervention systems for children with ASD geared towards promoting engagement and socialization. To reach our goal, we have conducted a number of research projects, where we have put a special interest in design, development and evaluation to contribute to the state of the art. Our efforts have lead to the following contributions:

- We have analyzed and justified design processes to adequately exploit the specificities of full-body interaction in the context of interventions specially conceived for children in the Autism Spectrum Disorder. This has led to general design guidelines. These design guidelines are a result of the evaluation and analysis of results from the three previous presented project (Chapter 7).

- We have analyzed the existing evaluation methods and we have critically developed new approaches to evaluate the effects of the designs of full-body interactive experiences.

- We have developed a full-body interaction system for music therapy aimed at promoting and maintaining user's engagement through fostering exploration and discovery. The system is called SIIMTA and we validated its success on achieving desired goals. Results showed that the game fostered diversification of activity (Chapter 3).

- We have developed another full-body interaction system, based on the Microsoft Kinect camera, for promoting social behaviors in young children with ASD. This project was part of the European Commission research project "Motion-based adaptable playful learning experiences for children with motor and intellectual disabilities" (M4ALL). We have validated the system through an experimental evaluation with a total of 15 children with ASD. Results showed that the game was effective in fostering social initiation behaviors (Chapter 4).

- We have developed a full-body interaction installation based on a large-scale projection on the floor (6 meters of diameter) where two children, one child with ASD and one neurotypical child, play together. The system is called Lands of Fog and was funded by the RecerCaixa 2013 scholarships. We assessed Lands of Fog performance in eliciting socialization and collaboration between users, where results show its efficacy (Chapter 5).

- We have published a series of articles and papers in different conferences and journals related to the projects. In the next section there is a list of publications done related to each one of the three projects we present.

1.2.1 Publications

In this section we present the publications derived from this PhD Thesis. We would like to clarify that in those in which the author of this thesis is not first author, he has nonetheless contributed decisively to both the research, the development of the systems and the writing of the paper. We will sort the publications given the name of the research projects we present in this thesis.

Published

- Laura Malinverni, Joan Mora-Guiard, Narcis Pares (2016) Towards methods for evaluating and communicating participatory design: A multimodal approach. International Journal of Human-Computer Studies, Volume 94, October 2016. pp. 53-63.
  doi: 10.1016/j.ijhcs.2016.03.004
  - The article presents the use of multimodal analysis to analyze users contributions in Participatory Design in a case study with 4 children with ASD.
  - In the article we demonstrate that multimodal analysis effectively grasped contributions across different resources.
  - The contributions of our design process are presented as useful bullet points for guiding design of serious games in interdisciplinary teams.
- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Maria Angeles Mairena, Amaia Hervs, Narcis Pares (2014) Participatory design strategies to enhance the creative contribution of children with special needs. IDC '14: Proceedings of the 2014 conference on Interaction design and children. pp. 85-94. ISBN: 978-1-4503-2272-0
  doi: 10.1145/2593968.2593981

  - The paper presents the participatory design process carried out with children with ASD for the design of a Kinect motion-based game aimed at fostering social initiation skills.
  - We suggest possible approaches aimed toward widening the space for contributions of children and including them at a more creative level.
  - The article discusses the "empowering dimension" of participatory design activities as an instrument to enhance benefits both for design results and for the children themselves.

- Joan Mora-Guiard, Laura Malinverni, Narcis Pares. (2014) Narrative-based elicitation: orchestrating contributions from experts and children. CHI EA '14: CHI '14 Extended Abstracts on Human Factors in Computing Systems. doi: 10.1145/2559206.2581292
  - This paper presents a way for organizing how different stakeholders can work together for the design of a system for children with ASD.
- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Amaia Hervas, Narcis Pares (2014) Picos Adventure: A Kinect Game to Promote Social Initiation in Children with Autism Spectrum Disorder. In the proceedings of the ITASD 2014 2nd International Conference on Innovative Technologies for Autism, At Paris, France.
  - The poster presents the development of a Microsoft Kinect based game for children with ASD to foster social initiation.
  - The poster also presents preliminary results of a exploratory study with 10 children with ASD.
- Joan Mora-Guiard, Narcis Pares (2014) "Child as the measure of all things": the body as a referent in designing a museum exhibit to understand the nanoscale. IDC '14: Proceedings of the 2014 conference on Interaction design and children. pp. 27-36. ISBN: 978-1-4503-2272-0 doi: 10.1145/2593968.2593985

   - The article explores the potentialities and affordances of full-body interaction, embodied by a large multi-touch surface and a large-scale floor projection, for the learning of the nanoscale concept.
   - In the article we present a study in a museum exhibition to evaluate the advantages of letting children to naturally manipulate the virtual objects through the multi-touch table, and understand the scale relation of the objects as they “miniaturize” themselves.
   - Results presented show that the system was effective on helping children better understand the scale relation between different objects from an everyday scale, represented by objects such as a 1 Euro coin, to the nanoscale objects.

Accepted (in press)

- Joan Mora-Guiard, Ciera Crowell, Narcis Pares, Pamela Heaton (In press) Sparking social initiation behaviors in children with Autism through Full-body Interaction. Special Issue on International Journal of Child-Computer Interaction in Designing with and for Children with Special Needs.
   - The article presents the full-body interaction system Lands of Fog, a multi-user experience designed with and for children with ASD to foster social initiation and collaborative behaviors.
   - In the article we present the two studies carried out for the assessment of the Lands of Fog system.
   - The article finishes with the presentation of the results obtained from three different data gathering methods, and how these show the efficacy of the system towards engaging the user, fostering socialization and motivating collaboration between users.
- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Lilia Valero, Amaia Hervas, Narcis Pares (In press) An inclusive design approach

for developing video games for children with Autism Spectrum Disorder. Journal of Computers in Human Behavior.
doi: 10.1016/j.chb.2016.01.018

  - The article presents an inclusive approach for designing games for children with special needs.
  - The goal of the method presented is to design games that are effective in terms of therapeutic objectives and that are enjoyable for children.
  - To describe the method, we present its application in the design and development of a Microsoft Kinect based game for high-functioning children with ASD called Pico's Adventure.
  - We present in the article a definition of design concepts useful to foster social initiation and exploration.

- Joan Mora-Guiard, Ciera Crowell, Narcis Pares, Pamela Heaton (In press) Lands of Fog: Helping Children with Autism in Social Interaction through a Full-Body Interactive Experience. IDC '16: Proceedings of the 2016 conference on Interaction design and children. doi: 10.1145/2930674.2930695

  - The article presents the design of a full-body interaction experience called Lands of Fog, in which a child with ASD plays together with a typically developed child.
  - The article focuses on the description of the interaction design process, methods and criteria that support the final experience. These are presented as potential guidelines for designing new similar systems.
  - We then provide preliminary results from the user trials which provide a first hint of the efficacy of the system in fostering users engagement and making socialization attitudes emerge.

Submitted

- Joan Mora-Guaird, Laura Malinverni, Narcis Pares (Submitted) Designing a kinect-based a multi-user videogame for fostering social behaviors in children with ASD.
  - The article focuses on explaining the process of converting therapeutic goals and challenges to game mechanics and the interaction design strategies adopted. It explains the process in relation to the physical interface chosen and its capacities and limitations.
  - The article does a thorough analysis of the results in relation to the game mechanics to present a series of suggestions for the interaction design of other full-body interaction serious games aimed ad fostering social initiation for children with ASD.
- Joan Mora-Guiard, Laura Malinverni, Maria Angeles de Mairena, Amaia Hervas, Narcis Pares (Submitted) Pico's Adventure: an interactive experience to promote social initiation in children with autism.
  - The article mainly focuses on explaining the results obtained from Pico's Adventure experimental assessment. The focus of the article is for Psychology Journals.

1.3 Thesis structure

We start this thesis with Chapter 2 where we present the state of the art and an introduction to topics related to this research. We first introduce Autism and the challenges related to it in Section 2.1. We present a review of some of the existing therapies for ASD in Section 2.1.2. We follow with an introduction to the theoretical underpinnings to the kind of interaction we focus on this thesis in Section 2.2. We review the state of the art of ICT designed for ASD in Section 2.3. We finish the chapter with a summary of the theory presented and our approach to try to contribute in this field of knowledge as interaction designers.

In Chapter 3, we describe the design process, the development and the evaluation of the SIIMTA research project, the first of the three projects we present in this thesis for the exploration of full-body interaction and the definition of guidelines for the design of new systems. The system presented is a music therapy experience for children with severe ASD to keep their engagement within therapy sessions. With this project, we demonstrate that full-body interaction is a suitable approximation for developing systems to engage users and motivate them to explore virtual environments.

In Chapter 4, we introduce the Kinect based project Pico's Adventure. We first present the design process of the game, focusing mainly on the translation of therapeutic goals to interaction mechanics. We follow the chapter with explaining the development and the evaluation process we conducted for validating our project. With this project, we demonstrate that full-body interaction systems are suitable for fostering socialization, but moreover, they have unique opportunities to foster specific social gestures, which would not be possible to achieve with other interactive means.

In Chapter 5, we present the Lands of Fog project. For this full-body interaction project, we keep the structure of first introducing the design process, from goals to game mechanics. We then explain the development of the system, both the videogame and the tracking system necessary to achieve the kind of interaction we pursued. Finally, we explain the two experimental procedures we conducted, one in Barcelona and one in London. This project proofs that full-body interaction is specially suited for developing collocated systems, where users are encouraged to socialize and to collaborate.

Finally, in Chapter 6, we compile all contributions of the three projects presented and we categorize them with tables for classifying full-body interaction systems for children with ASD taking into account interaction, content and objectives. In Chapter 7 we present a series of guidelines for designing similar systems and we talk about the limitations and future work of this thesis.

Chapter 2

State of the Art

In this chapter, we start with an explanation of Autism Spectrum Disorder in Section 2.1 and a detailed explanation on how we approached it. We describe the challenges derived from the impairments associated to the disorder in 2.1.1. Both sections are a brief but useful introduction for understanding the goals and requirements of the work that we present in this thesis. Then we do a brief introduction to three different approaches to therapy for individuals with ASD in 2.1.2. We specially focus on these three approaches, since each one of those has been taken separately into account for the design of the three systems presented in this work. Later we introduce the theoretical underpinnings to Full-Body Interaction. In Section 2.2, we review the philosophical and psychological approaches to Embodied Cognition to better understand the unique cognitive potentials of this HCI paradigm. Second, we talk about how these theories have been adopted in the HCI domain in Section 2.2.2. We finish the State of the Art chapter by doing a general overview of the story of Information and Communication Technologies for individuals with ASD in Section 2.3, and we finally focus on full-body interaction for ASD in Section 2.4.

2.1 Autism

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by behavioral abnormalities in the domain of social communication, and also by restricted and repetitive behaviors, interests and activities (Association 2013). The challenges in social communication were addressed in the Pico's Adventure project, Chapter 4, and the Lands of Fog project, Chapter 5. The characteristic of limited behaviors were taken into account when designing the system called SIIMTA, presented in Chapter 3. ASD is a prevalent developmental disorder, having an estimated prevalence of about 1.47% to 2,64% of total population with a relation male/female close to 5/1 (Kim et al. 2011; Christensen et al. 2016). In the experiments in Chapter 3 and in Chapter 5, we achieved a close gender ratio when recruiting population. Current ASD diagnosis is based on different sources, such as standard assessments, observing the individual in different structured scenarios, or the knowledge of therapists and caregivers who treat the individual (Filipek et al. 2000). Individuals who are diagnosed with ASD show a broad range of symptoms (Tager-Flusberg and Joseph 2003). Even individuals with the same severity level in ASD diagnostic tests may present a wide range of manifesting symptoms.

There exists a number of diagnostic tools addressed to assess whether a subject is within the ASD and the severity level of the symptoms. These tools can also be used for defining inclusion criteria in experimental assessment. One such tool is the Autism Diagnostic Observation Schedule (ADOS) (Lord et al. 2000), based on a set of structured and semi-structured activities that psychologists undertake with subjects, which are later evaluated and categorized for a final quantitative score. The ADOS tool is divided into 4 modules, each one specific for an age group and a level of verbal capacity, namely: Module 1 is for children with little or no speech, Module 2 for children with little speech but no verbal fluency, Module 3 is for verbally fluent children, and Module 4 is for verbally fluent adolescents or adults. Each module produces a score, which defines the level of autism severity (where 4 is the cutoff value for an ASD diagnosis). Another diagnostic instrument is the Autism Diagnostic Interview Revised (ADI-R) (Lord et al. 1994), which is a structured interview conducted with the parents of the individuals with a potential ASD diagnosis. The tool is divided into three fields: social interaction, communication and language, and restricted and repetitive behaviors (as impairments defined by DSM-V (Association 2013)). Each category has a cutoff score for marking whether there is a significant abnormality in the assessed behaviors. Autism is diagnosed when all three scores exceed their cutoff values. In all three projects presented in this thesis, the ADOS diagnosis was an inclusion criteria for the participants of the experiments, being Module 1 and 2 for the project presented in Chapter 3 and Module 3 and 4 for both Chapters 4 and 5.

Some psychological theories for ASD claim that individuals with this disorder like predictability and systematic or highly structured information. The Mind Blindness theory claims that people with ASD suffer a delay in developing a theory of mind (capacity of "reading" others mind) (Frith 2001). Individuals with ASD may be puzzled by others' behavior, as it might be perceived as unpredictable. The Empathizing-Systemizing theory (Baron-Cohen 2009) proposed that people with ASD tend to systematize (i.e. to analyze and construct systems) above the average of typically developing (TD) people. Although these psychological theories do not account for all individuals with ASD, their psychological explanations can be taken into account for partially explaining or understanding ASD. The systems presented in this thesis have always sought for a structuredness that could be appealing for individuals with ASD, but always adding space for improvisation, trying to scaffold and foster exploration and through discovery, promote socialization. Alcorn et al. suggest that discrepancies and events that violate the rules of the virtual environment motivated a wide range of social initiation in children with ASD interacting with the digital game ECHOES (Alcorn et al. 2013). Thus, we believe that when designing interactive systems for children with ASD, we must find, through experience design, the correct balance between structuredness and improvisation with surprising and unexpected elements.

Research and therapies tend to focus on specific sub-groups, such as high or low functioning level, for better adapting their work to characteristics specific to a range of the spectrum. There are two terms mostly used to classify individuals in the higher and the lower levels of functioning in the ASD: low-functioning autism (LFA) and high-functioning autism (HFA). None of the two terms are recognized diagnosis in the DMS-V (Association 2013). LFA term was coined to refer to the range of autism at the most severe end of the spectrum. Individuals who are tagged in this sub-group often show most extensive impairments and tend to have little or no language skills, low IQ and severe motor difficulties. This was the objective population for SIIMTA (Chapter 3), a system designed for fostering engagement and exploratory behaviors for Music Therapy sessions.

HFA is defined by having a diagnosis of ASD and an IQ higher than 70, and this sub-group of people are believed to have higher chances of leading an autonomous life, if properly assisted in youth. Although normal intellectual capacity, this sub-group can also show meaningful social communication deficits (Roeyers 1994), making fundamental the improvement of their social functioning (Rogers 2000) in early age. The Pico's Adventure full-body interaction system (Chapter 4) focuses on the promotion and learning of social skills and behaviors for young children with HFASD. Although individuals with HFA show normative performances in social capacities through structured social tests (van der Geest et al.), in more spontaneous, real-time social scenarios there are discrepancies in their performance when compared to neurotypical individuals with similar IQ and age (Klin et al. 2003). The project Lands of Fog (Chapter 5) was designed to offer a scaffolded environment to promote serendipitous social engagements between youngsters with HFASD and neurotypical children.

2.1.1 Challenges

Social impairments are probably the most important deficit in ASD children and social initiation represents a fundamental aspect for the proper development of social skills. Even if children with ASD can learn to respond to social initiations started by others, they may present major difficulties in initiating this social interaction by themselves. As a result, social interaction may be compromised (Nikopoulos and Keenan 2003). At the same time, a study showed that when social initiation rate increases, it leads to a significant improvement in social behaviors (Strain et al. 1979).

For individuals with ASD forming and maintaining relationships with peers may be challenging and problematic due to deficits in social communication skills. For example, unspoken social norms and expectations can be difficult to grasp for people with ASD, as they are typically coordinated through non-verbal interactions with others (De Jaegher 2013). Individuals with ASD also have problems with interpreting others' speech by not taking into account contextual information, which can lead to misunderstandings regarding non-literal elements of the conversation (Grynszpan et al. 2008). Moreover, individuals with ASD have problems engaging socially as they often do not properly understand the way they are being perceived by other interlocutors (Bauminger-Zviely et al. 2014). Studies on unstructured playground dynamics suggest that children with ASD may show a higher frequency of engaging in solitary, nonsocial play than their typically developed counterparts (Bauminger et al. 2010; Kasari et al. 2012; Symes and Humphrey 2011).

Difficulties forming and maintaining relationships with peers may lead to an increase in social fragmentation in school contexts for children with ASD (Anderson et al. 2015). The challenges on establishing social relationships are in consonance with the difficulties individuals with ASD have to communicate and start a social interaction with unknown people (Kasari et al. 2008). Furthermore, difficulties in social relationships can affect individuals learning abilities (Bolic Baric et al. 2016). Thus, it might be necessary to provide support during unstructured social scenarios to counter social fragmentation (Anderson et al. 2015). A recent study in school-based intervention programs designed to improve social experiences, presents findings that young people with ASD prefer activity-based learning with peers rather than direct instruction activities (Bottema-Beutel et al. 2015).

Another challenge which is also pervasive in individuals with autism are motor skills impairments (MacDonald et al. 2014). In their research, MacDonald et al. found a significative correlation between deficiencies in fine and gross motor skills, and autism severity. Although motor skills challenges are not specific to autism, given the description in the DMS-V (Association 2013), their prevalence is really high in some studies about motor skills in people with ASD (Klin et al. 1995; Hughes 1996; Perkins 1997; Gillberg and Kadesjö 2003; Liu 2013).

As stated in Section 2.1 ASD is characterized by restricted and repetitive behaviors, interests and activities (Association 2013), which normally lead to stereotypy or passivity (Gabriels et al. 2005). Stereotypies can be understood as repetitive, close to ritualistic, movements and utterances. The kind of behaviors that stereotypy refer go from body-rocking, to repetitive sensory self-stimulation. These abnormal behaviors can lead to an aggravation on the potential motor skills deficits characteristic of ASD (Johnson and Myers 2007). Nonetheless, there is evidence that stereotypy can be reduced through positive reinforcements to teach children to diversify their activity (Eason et al. 1982).

2.1.2 Interventions

Early intervention is seen as crucial in raising the benefits of any sort of assistance (Warren et al. 2011). There is research evidence that early intervention leads to better outcomes of the therapy compared to being applied in older age (Corsello 2005; Warren et al. 2011), thus it is mandatory to develop programs and tools that allow for an early intervention for ASD children. Early educational interventions can improve ASD children's quality of life by modifying challenging autistic behaviors (Carr 1977) and promoting learning of social communication (Baron-Cohen 2008). More specifically, research has shown that early intervention in children with HFASD has better progress reports (Zachor and Ben Itzchak 2010; Rao et al. 2008).

Play Therapy

Play therapy is a set of play-based interventions, where a therapist builds communication with patients through driving play activities towards patients' interests. It is most commonly used as an intervention for the development of social and communication skills. Research evidences the benefits of play-based therapy for the acquisition of social and communication skills (Casenhiser et al. 2013; Green et al. 2010; Kasari et al. 2008; Mahoney and Perales 2003; Pajareya and Nopmaneejumruslers 2011). For Caillois, play has a certain degree of freedom and interpretation inside certain limits imposed by de facto rules or objects' affordances (Caillois and Barash 1961). Thus, play can have potential as a therapy mediator given its structured nature, but upon its structured nature participants can build new needs and interactions. When designing some of the playful experiences presented in this thesis, we took into account the aforementioned fact by designing systems with an initial simple and predictable nature, upon which we were able to build more complex mechanics.

Children with ASD tend to show non-common behaviors in imaginative and symbolic play when interacting with toys. They may persist on objects, use them for self-stimulation, and become entirely self-absorbed in these behaviors. Their approach to objects and toys tend to be an exploration through taste and caress (Rowland and Schweigert 2009; Williams 2003), being more intimate and close to the objects than neurotypical people. This means that playing is also crucial in children with ASD for the development of social and communication skills like it is in TD children, but that they might just approach in different manners to playing.

One of the most successful and known research on play-based therapy for ASD children is by Daniel Legoff (LeGoff 2004). Legoff used LEGO brick sets as a tool for mediating communication between groups of children with HFASD. During experimental sessions each child had a specific role in the building process, thus all children in each group were forced to cooperate and collaborate for achieving the final goal. The results showed an improvement in the acquisition of social abilities, specifically initialization of peer contact. A long-term study found a significant improvement on the acquisition of social competence skills compared to the control group (Legoff and Sherman 2006). We have adopted this strategy by implementing, both in Pico's Adventure (Chapter 4) and Lands of Fog (Chapter 5) projects, game scenarios where users are encouraged to collaborate for achieving a common goal. Ben-Sasson et al. explored the benefits of designing games through the strategy of "enforced collaboration", a design strategy where two children had to do things together to solve a puzzle, compared to a "free play" approach (Ben-Sasson et al. 2013). Results showed that enforced collaboration led to a higher degree of interaction and negotiation, but also an opposite effect of elevated frustration and off-task behaviors, when "forced by technology to collaborate. By implementing collaboration scenarios, we believe we can foster children to socialize and help them learn the benefits of doing so. But we do also believe it is important to give users their space, thus, we tested a non-enforced, but suggested, collaboration approach in Lands of Fog project, which we called "encouraged collaboration" (see Section 5.2).

Music Therapy

Bruscia defines Music Therapy (MT) as "a systematic process of intervention where the therapist helps the client to promote health, using musical experiences and the relationships that develop through them as dynamic forces of change" (Bruscia 1998). For Berger MT is "[..] based on observations, insights and informed assumptions. Music therapy does not replace other interventions, nor does it need to copy the goals of other therapies in order to be effective" (Berger 2002).

Music serves as a structured, predictable and at the same time flexible communication channel between the therapist and the patient. Wigram and Grocke suggested that creative skills in children with ASD should be fostered from a structured therapy upon which they can start creating needs (i.e. improvise) (Grocke and Wigram 2006). Thus, MT is a "working frame" where therapists create a functional musical structure for communicating with the ASD children (Wigram 2004). This idea was taken into account when designing SIIMTA (Chapter 3) in order to specify a discrete and structured sound space, which could be experienced by children with ASD to promote exploration and creativity.

Moreover research shows that ASD people have better pitch processing and memory than TD people (Heaton et al. 1998; Bonnel et al. 2003). This affinity to music can be argued as a higher capacity of people with autism to develop musical skills and use sound as a mean of communication (P. HEATON et al. 1999), thus developing therapy around Music seems a suitable approach when working with individuals with ASD.

Studies show that MT might have greater benefits for ASD children than other conventional therapies like play sessions (Kim et al. 2008). Kim compared a group that received music therapy sessions with another group that did game therapy sessions. The former group showed a greater improvement of acquisition of joint attention abilities. Nonetheless, we believe that both approaches have their own benefits and could be even combined. There is also evidence on the benefits of combining music therapy with traditional ABA intervention for specific skills (e.g. echoic production) in ASD children (Lim and Draper 2011).

Applied Behavioral Analysis Intervention

The most prevalent interventions for improving individuals with ASD quality of life are the Applied Behavioral Analysis (ABA) based interventions (Cebula 2012; Johnston et al. 2006; Reichow et al. 2012; Vivanti et al. 2013). ABA is based on shaping behavior and the teaching of new skills using positive reinforcement. It commonly acknowledged that ABA techniques can produce improvements in communication abilities, social behaviors, play skill, and can foster skills such as looking and imitating, as well as reading and understanding another person's perspective (Dawson et al. 2012; Eapen et al. 2013; Grindle et al. 2012). Different ABA based interventions have been adopted widely. One of them is the Early Intensive Behavioral Intervention (EIBI) Lovaas Model by Dr. Ivar Lovaas, which went under approval by the United States Surgeon General's office in 1999 (Lovaas). Another example is the Early Start Denver Model (ESDM) by Dr. Geraldine Dawson and Dr. Sally Rogers (Dawson et al. 2012). Despite most ABA interventions have been designed for children, given the benefits of early intervention, some studies prove that ABA techniques can be applied to the whole age spectrum of autistic people (Kasari et al. 2010).

Different reinforcements can be given to patients depending on the exercise or the user itself and its preferences. These reinforcements vary from verbal feedback during modeling process to audiovisual stimulus. During therapy whenever a desired behavior is achieved by the children, therapists give verbal aids to reinforce it. Furthermore, the same activities may have visual and audio cues that can be pleasant to patients and which are used also as reinforcements. For this, full-body interaction might have unique potentialities for designing systems for individuals with ASD thanks to its digital nature, which allows to design systems that give immediate audiovisual feedback whenever users do the behaviors expected by therapists.

In 2002 Edward Carr, based on his previous research on explaining and anticipating problematic behavior by ASD people, presented the Positive Behavior Support (PBS) (Carr et al. 2002). For Carr, challenging behavior is a functional way for ASD people to express their feelings. Thus, for a correct intervention it is essential to first understand the context where these behaviors arise through functional behavior assessment (FBA). The FBA not just takes into account the trigger stimuli for the problematic but the setting events of the behavior burst (e.g. health status, social context, actual activity). The setting events can be of social, activity or biological nature, and they ultimately translate to arousal, whether positive or negative, of the ASD person in a given moment. We have taken this into account by designing systems which try to understand the context of interaction, and act appropriately. In Chapter 4, we applied this in the Pico's Adventure project by making the virtual agent react to user's behavior. When user was passive, the virtual character would try to catch its attention by requests or greetings, while if user caressed it, the agent would react with a positive social feedback such as smiling. In the project Lands of Fog (Chapter 5) we designed some of the interactive elements to adapt to users' behavior, so if they show signs of passiveness or not grasping some of the interaction mechanics, the virtual elements would adapt their behavior to try to help children. Also, quick positive feedback was given in both aforementioned projects every time users collaborated, to reinforce positive attitudes.

We have designed the projects Pico's Adventure (Chapter 4) and the Lands of Fog project (Chapter 5) applying ABA principles. We designed both projects alongside the Specialized Unit on Developmental Disorders from Sant Joan de Déu Hospital, in Barcelona, who are specialists in ABA therapy. Thus, the specialists and psychologists from the center informed us the therapeutic goals, requirements and design of the full-body interaction system.

2.2 Embodied Cognition

Embodied Cognition encloses theories and disciplines from different fields such as philosophy, psychology or even cognitive science, all which argue that cognitive processes are mediated by the body and the fact that our body is actively embedded in the environment, which is populated by objects and other subjects. The paradigm shift from a Cartesian view of cognition (i.e. the view that cognitive phenomena is detached from physical phenomena) to an embodied standpoint started during the 20th century in the philosophy domain.

2.2.1 Currents Associated to Embodied Cognition

In philosophy the change in understanding cognition began with the philosophical discipline known as Phenomenology, which appeared during the first half of the 20th century thanks to the work of Edmund Husserl (Husserl 1977). The phenomenology discipline was settled down thanks to philosophers such as Husserl's disciple Martin Heidegger, or Maurice Merleau-Ponty (Merleau-Ponty 2002), who stressed the triadic relationship between the world, the body being situated in it, and the time constrained experience. Phenomenology studies how subjective consciousness and knowledge arise from how we perceive, experience and act within the world mediated by our own body (Cerbone 2006).

In the psychopedagogy domain the relation between environment and physical experience is reflected in Piaget's Constructivist Theory. Piaget proposes that cognitive development is based on the "detachment" of knowledge from the world of concrete objects to the world of abstract and symbolic objects. The changes in children cognitive processes (i.e. the construction and acquisition of knowledge) emerge as a result of their activity within the world (Ackermann 2004). This idea of action, or activity, is also found in Leontiev's Activity Theory (Wertsch 1981). Activity Theory states that psychological processes (i.e. cognitive processes) emerge from the activity of humans in the social environment and the artifacts within it. Inter-psychological processes, those that take place in the physical world, are necessary for the development of intra-psychological processes (i.e. cognitive processes such as learning). Vygotsky called this process "Internalization" (Wertsch 1985), which is in consonance with Piaget's constructivist model. Furthermore, the idea that cognition is also based in participatory sense-making, cognition based in social interactions, which are fundamentally based on engagement between agents is also known as "Participatory sense-making" (Fuchs and De Jaegher 2009). This engagement between agents is the feeling of conectedness and flow between them, a bi-directional influence and coordination process. We colloboratively generate meaning through active participation in the world, influencing each others sense-making processes.

In cognitive science, the relation between cognition, activity and emergence of knowledge is normally referred as situatedness (Hendriks-Jansen 1996). In the Artificial Intelligence field, this approach is clear in Brooks' robotics research on developing robots which behavior is based on their embodiment and situatedness, i.e. their capacity of sensing the environment and acting upon it (Brooks 1999). This idea is also shared by Enactivism. The enactive cognition approach defines that cognition is inherently embodied given that how we perceive the world as agents depends on our autonomy, our inner states and needs, and this is how we act for the sense-making part (Di Paolo et al. 2010).

All these theories ground the importance of the body, other subjects, the environment and the objects in it, on the construction of cognitive processes and hence, on the learning and acquisition of knowledge. For Hanne De Jaegher it seems that allowing children to experience learning activities where there is a freedom for repetitive interests and behaviors might be motivating for ASD people, fostering the learning outcomes of the experience, proper behaviors and social interactions when working with peers (De Jaegher 2013). When designing our systems, we have taken into account that full-body interaction systems can allow users to experience the world and act in it in a 1:1 relationships. These systems can also be adapted easily to a large format that would allow for collocatedness, thus offering environments where objects and subjects are together.

2.2.2 Embodied Interaction

Alongside these theories, the importance of the body in the HCI domain has been fostered by the evolution of computers and computing devices and by the increasing interest of including more possibilities in the way humans interact with computers (Buxton 1990). As Grudin proposed, the history of computing is that of "the computer reaching out" (Grudin 1990). In this history, new kinds of sensors, such as multi-touch screens (led nowadays by smartphones and tablets), Microsoft's Kinect, Nintendo's Wii or Leap Motion, have helped in the process. New hardware has lead to new ways of achieving communication between computing devices and users. More natural interactions are being explored. Multi-touch surfaces allow "direct manipulation" of virtual objects, while advances in tracking interfaces (e.g. accelerometers, infrared cameras, 3D tracking systems, etc.) opened the door to full-body interaction.

Nonetheless, this new paradigm of HCI can not be only based in the evolution of technologies for interacting with computers. We believe it is important to understand how these technologies affect how users perceive the interaction process and the digital content through the experience of interacting. Moreover, it is important to also understand the unique affordances and potentialities of these technologies. In this thesis we are actually focusing on this matter by exploring how full-body interaction technologies can be used for the development of systems for children with ASD.

In his seminal book "Where the Action is" (Dourish 2004), which deeply influenced the HCI field by relating new technologies and embodied cognition theories, Dourish derives the concept of "Embodied Interaction" from phenomenology. One of the major lessons he draws is that embodiment is about the relationship between action and meaning (Dourish, 2004, p. 126). Embodiment is not just about being physically in the world, but also being in a "participative status" within it. The new myriad of technologies available allow for the development of novel systems which are more "aware" of the users. Moreover, these new technological approaches allow for a wider range of motor abilities to be involved in the HCI, thus opening the possibility of offering systems where the user is "present" in the virtual world. Moreover, embodied interaction seem to have unique potentialities for developing collocated systems which allow for direct natural manipulation of the virtual environment (Antle 2013; Dillenbourg and Evans 2011).

Full-Body Interaction, being based in embodied cognition theories, seems to have a unique potential for developing systems to support learning (Goldin-Meadow 2011; Revelle 2013). In the last years, there has been an increasing interest in the use of full-body interaction to develop virtual environments to support learning (Malinverni and Pares 2014). Research shows that navigating through physical environments allows a better creation of a mental model and deeper understanding of one's surroundings than simply viewing a two-dimensional representation (Bartoli et al. 2013). In addition, full-body interactive environments allow for the body and gestures to become the focus, as participants may operate the system through natural kinesthetic movements (Grandhi et al. 2011; Nielsen et al. 2004). In this respect, we believe that full-body interactive environments which allow for the use of body language and communication gestures could be particularly useful for facilitating social understanding, making this kind of media more suitable for developing systems for children with ASD and focused to socialization and collaboration.

2.3 Autism and ICT

As stated in Section 2.1 social communication impairments may represent the most important deficit for people with ASD (Roeyers 1994) and improved social functioning is considered one of the most important intervention outcomes (Rogers 2000). For this purpose a range of treatments have been designed, evaluated and published in ASD literature. However the effectiveness of the treatments is mainly associated with their continuity and intensity in terms of weekly hours (Boyd et al. 2014). Requirements related to the intensive nature of the treatment led mental health professionals to explore the use of digital games to complement traditional treatment methods (Goh et al. 2008). Such direction approach is based on the interest that children have shown in digital games and the capacity of games for inducing motivation and engagement (Prensky 2003; Resnick 2002) and producing behavioral changes (Deterding et al. 2011). Moreover, game-based interventions with children within the ASD have been proven to accelerate learning processes (Charlton et al. 2004), by reducing the need for supplementary rewards and by increasing the willingness to complete the required tasks (Hoque et al. 2009). These findings have lead to a widespread proliferation of digital games for ASD children in a large diversity of platforms and technologies.

Moreover, Brown and Murray, while researching how to engage children with ASD, found that this population has an affinity towards information and communication technologies (ICT) thanks to their linearity and discreteness (Brown and Murray 2001). This also influenced that in the last two decades there has been an increasing interest towards research focused on the use of ICT therapies for people with ASD. For years there has been a growing number of treatment strategies that include interactive technologies which are useful and attractive for children with ASD (Goldsmith and LeBlanc 2003). In addition to being appealing to children with ASD because they feel comfortable in its context, computer-based technologies are ideal to present scenarios which can give immediate and consistent feedback to children with ASD (Moore and Calvert), which attunes to the idea seen in Section 2.1.2. Nonetheless, we believe that the most important benefits are that ICT technologies also allow for change to be introduced and regulated gently (Alcorn et al. 2011b), offering pleasant scenarios for children with ASD which can gently evolve to more sophisticated and complex scenarios, making this approach suitable for developing therapy and intervention where users are more comfortable. Given these premises, Davis et al. (Davis et al. 2010) recommended developing ICT with design features which would be readily accepted by individuals with ASD in therapy settings, such as task consistency and predictability as well as the gradual introduction of novel elements.

One of the first interactive technology systems to be designed for children with ASD was the MEDIATE project. MEDIATE was a multimodal adaptive physical environment for children with severe autism with the aim of providing them with a sense of control through interaction and, hence, provide them with a sense of agency (Parés et al.). MEDIATE was also a forerunner on designing ICT experiences as complementary tools for therapist and caregivers, as it was meant to be a safe space for children with ASD so they could play in a controlled environment and express themselves freely. The project presented in Chapter 3 uses part of the design principles and knowledge from the MEDIATE project.

Existing research recognizes the effectiveness of technology for the acquisition of new skills by children with ASD. In the field of Video Modeling (i.e. the teaching process of video recording and displaying content as a visual support for the target skill or behavior) research has shown the benefits of using ICT for achieving task completion abilities (Mechling et al. 2006; Hayes et al. 2010). Desktop multimedia has also been widely used to support teaching for the recognition of complex emotions in face and voice (i.e. Mind Reading abilities) (Golan and Baron-Cohen), maintaining appropriate spatial boundaries in social interaction (Tentori and Hayes 2010) or even fostering language acquisition (Bosseler and Massaro 2003; Tartaro and Cassell 2008). Opportunities to utilize ICT-based therapies and interventions for children with ASD also include the use of handheld devices for aiding communication (Dyches et al. 2002; Mirenda 2003).

Finally, Virtual Environments (VE) have proven to be a way to reduce anxiety while simultaneously forming behavioral patterns. One example is the AS Interactive Project by Parsons, et al. (Parsons et al. 2006) in which ASD children were trained in a variety of virtual social scenarios, such as finding a seat in a cafe or on a bus. Projects involving individuals with ASD can be categorized into either single user virtual environments (SVE) or collaborative virtual environments (CVE) (Moore et al. 2005), depending on the user capacity and desired functionality of the project.

In the following sections we will do an overview of different technologies used for different purposes for individuals with ASD. We will start with general research focused towards specific skills such as emotion recognition or crossing a road. The two following sections will focus on basic socialization and specific social behaviors respectively. In each section we will order the research given the technology in sue, from multimedia applications for Desktop computers, to Virtual Environments accessed through non full-body interaction approaches.

2.3.1 Learning of non-social specific skills

We focus this thesis on the use of technology for promoting engagement and social behaviors, but we believe it is important to first do a brief review of existing technologies for other contexts. Existing research recognizes the effectiveness of technology for the acquisition of new skills not related to social communication by children with ASD. In the domain of Video Modelling (i.e. the teaching process of displaying video recordings as a visual support for the target skill or behavior) there are evidences of its benefits for achieving task completion (Mechling et al. 2006; Kimball et al.; Hayes et al. 2010). Teaching within a desktop computer context has also been successful for the acquisition of reading and listening skills (Coleman-Martin et al. 2005; Tuedor 2006; Massaro and Bosseler 2006; Luckevich 2008). Both Video Modelling and Desktop applications tend to be SVEs, limiting the learning processes to only the digital content users can access.

Handheld technology has been used also as a support for the teaching of Mind Reading abilities (i.e. recognition of complex emotions in face and voice) (Golan and Baron-Cohen 2006) or even "interaction immediacy", maintaining appropriate spatial boundaries in social interaction (Tentori and Hayes 2010). Given their portable nature, handheld devices can be used both for developing single user and multiple user environments, but still, limit the content visualization to an individualistic fashion (for each user's handheld).

In 1996 Dr. Dorothy Strickland examined whether ASD children would tolerate Head Mounted Display (HMD) technology for Virtual Reality (VR) (Strickland 1996) for teaching road-crossing abilities. Results of the research indicated that ASD children who tolerated the HMD were successful with the road-crossing task. However, only two children were actually studied.

In the field of VEs, research focuses on the positive potentialities of mediating collaborative environments (Cheng and Ye 2010; Millen et al. 2010). In 2009 Passerino presented the EDUQUITO project, a Virtual Learning Environment (VLE) for mediating social interaction between autistic children in an educational frame (Passerino and Santarosa 2008). The project assessed the benefits of a web application to help ASD children share and communicate knowledge.

2.3.2 Motivating social interaction

Most ICT research has been focused on the acquisition of social and communication skills, but before learning specific skills we must foster the desired behaviors.

One of the ICT fields which is really focused on motivating socialization and basic social skills is robotics. In this field, research is mainly focused on imitation intervention. Imitation is important as an initial social function and in the development of social communication skills (Ingersoll 2008). Robots are less socially demanding and much more predictable than human beings, thus reducing the social avoidance mechanisms individuals with ASD tend to display in front of unpredictability (as seen in Section 2.1.1), and increasing focused attention on users. Research on the use of robots with individuals with ASD show that users tend to exhibit more social behaviors such as imitation or joint attention. Dautenhahn research proved that children with ASD proactively approach to robots (Dautenhahn et al. 2002). Duquette et al explored the use of a robot as an imitation agent (Duquette et al. 2007). The results showed that children exposed to a robot mediator demonstrated more visual contact and proximity compared to children exposed to a human mediator. Robins et al. demonstrated that when acting as mediators, robots increase joint attention episodes between children and adult (Robins et al. 2004).

One example of collocated shared activity surfaces (SAS) was the Story Table (Bauminger et al. 2010). The research found that the use of a multi-user, multi-touch device had a positive effect on social interaction between two children with HFASD. The Join-In project also proved that collocated SAS intervention can have great potential for engaging users (Weiss et al. 2011). Another collocated experience is the Collaborative Puzzle Game by Ben-Sasson et al. (Ben-Sasson et al. 2013), which was based on completing puzzles on a SAS. The research compared two approaches, Free Play (FP), where each player could move any puzzle piece whenever they wanted, and Enforced Collaboration (EC), where both players were told to move the same puzzle piece in unison. Results showed that EC led to more interaction and negotiation, although the increased challenge in the EC versus FP mode led to a higher number of uncompleted trials and a lower positive effect than the FP approach. The EC approach was used in Pico's Adventure project (Chapter 4), where users had to collaborate if they wanted to progress in the adventure. In Lands of Fog project (Chapter 5) we adopted a different approach, which we named Encouraged Collaboration.

Existing research on Tangible User Interfaces (TUI) for intervention for ASD children has had also positive results as a mediator for the learning of social communication skills (Marwecki et al. 2013; Villafuerte et al. 2012; Farr et al. 2010). Results suggest that the use of mediating objects facilitates "computational offloading" of cognitive processes, thus facilitating the learning process by helping children to interpret other people's actions and intentions. Tangibles are also beneficial by helping children to channel their attention and providing a common context for sharing objects and ideas. In Lands of Fog (Chapter 5) we took this into account by implementing some pointing devices that would help users to better understand the relation between their activity and the virtual environment.

There is more research on the benefits of VE for teaching ASD children social skills (Parsons and Mitchell 2002; Kerr et al. 2002). Independently of the physical interface, VEs allow the design of controlled environments much more appealing to autistic children given their discrete and predictable nature. These approaches allow an individual to explore a virtual world and interact with virtual objects or characters in scenarios that can be similar to reality. In these environments, the designer can fully control the behavior of the virtual world, thus having a perfect scenario to mediate communication and learning for ASD children. Mitchell et al. experimented how VEs could help teaching social understanding to ASD children (Mitchell et al. 2007) with positive results. During the experiment they observed an improvement on social skills during the sessions, not confined to the particular virtual context of the application (a Virtual Café).

In the VE research there is an interest toward the potentialities and benefits of virtual agents. Virtual agents research is mostly focused on social competence and communication skill learning by ASD children (Alcorn et al. 2011a; Gray and Garand 1993; Hopkins et al. 2011). Like in robotics, the discrete nature of the digital peer helps ASD children to predict their behavior and reduce avoidance mechanisms in front of unexpected behavior. In Pico's Adventure (Chapter 4) we used a virtual agent as a way of motivating the child to engage with the system and ease the learning curve of the system.

In a more recent study, Fengfeng and Tami (Ke and Im 2013) evaluated the potential effect of a social interaction and communication program based on virtual reality for high functioning ASD children. Four children with HFA and seven control adults participated in the study. The program involved activities such as recognizing gestures and facial expressions, interacting in a cafeteria and interacting with others during a birthday party. According to results, participants showed an increase in their skills related to social initiation, responses and greeting during the intervention. Moreover, the authors observed some generalization, as participants improved their social competencies after the program.

2.3.3 Learning social communication skills

There is evidence that multimedia technology can help in the acquisition of social skills (Sansosti and Powell-Smith 2008). Within robotics research there is also research focused on the acquisition of social communication skills. Together, the Vrije Universiteit Brussel and Universitatea Babes-Bolyai have been exploring the potential of robots for the acquisition of social and emotional skills (Pop et al. 2013) with successful results. Kozima et al. used, with encouraging results, the robot Keepon to help children with ASD acquire social skills (Kozima et al. 2005).

In 2004 Strickland's research found positive results when using VR for teaching children with autism social skills necessary for being in a restaurant

(Strickland et al. 2007). The results of the research showed that half of the learned skills generalized to the real world.

In the field of VEs we can find the iSocial project, designed for teaching social skills to ASD children (Schmidt et al. 2008; Laffey et al. 2009). The scope of this project was to design and develop a VE based on positive social interaction, enabling learning of social competence skills. Yet another VE for promoting the learning of social competence by ASD children was the COSPATIAL project (Cobb et al. 2010). The project aimed to combine the success of the transfer of VE abilities to real world with the use of active and natural interaction input devices (Bauminger-Zviely et al. 2013).

2.4 Full-body Interaction

As previously argued in Section 2.2 learning is an active and physical process within the world in which body plays a significant part as mediator of knowledge acquisition. Taking the potentialities Information and Communication Technologies in the form of real-time interactive systems have for intervention for ASD children (Section 2.3), and the benefits of VEs as controlled realities in which therapy can be conducted, we can argue that full-body interactive experiences, as a mix of systems that take advantage of the mediation of the body within physical and virtual space, may provide a greater potential for intervention. The existing research on full-body interaction for intervention for ASD children is focused on the acquisition of agency, the learning of specific skills, the mediation of communication between therapist and patient, and the learning of social communication skills (Parés et al.; Tolentino et al.; Porayska-Pomsta et al. 2011; Casas et al. 2012).

One of the first approaches on full-body interaction for ASD children was the aforementioned MEDIATE project (Parés et al.). MEDIATE was designed "for children with autism to have fun and have the chance to play, explore, and be creative in a controllable and safe space" (Parés et al., p.2). The project was an interactive space with different sensors and actuators to work with different types of stimuli. MEDIATE had a "brain" based on a Signature Analyzer and a Decision Maker to establish a communication between the user and the system. The installation was capable of adapting itself to enhance user's interaction.

The Pictogram Room was a full-body interaction videogame in which pictograms were superimposed over the bodies of children with ASD. The purpose of the project was to help understand the relation between pictograms and the body. Moreover the project was aimed at supporting communication, joint attention and imitation therapy for social behavior learning (Casas et al. 2012). In this project an augmented reality approach was taken to superpose pictograms to the body gesticulation of children to easily communicate the relation between drawings and body.

Another full-body interactive project for acquiring social skills was The Echoes Project (Porayska-Pomsta et al. 2011). The scope of this project included developing a virtual environment which would encourage children with ASD between the ages of 5 and 7 to explore and acquire social interaction skills. The system was based on a virtual environment where a digital avatar was able to interact with the children. The system used an artificial vision subsystem to interact with the children and track children's focus towards the virtual objects. This way the system allowed for activities where joint attention, such as pointing, could be practiced.

In 2007 Keay-Bright started research on the development of a playfully exploratory system for ASD children in which they could easily explore different "magical" interactions without previous knowledge of the technology (Keay-Bright 2007). ReacTickles aimed to explore the possibilities of VEs to foster children opportunities of expressing themselves and foster immersion in the learning processes during playful intervention.

In recent years, Kinect has proved a useful technology for creating full-body interactive environments catered towards socialization in children with ASD. Autinect was a project that was aimed to help ASD children to learn social cues (Agarwal et al. 2012). The project challenged if human-virtual peer interaction potentialities for intervention for ASD children could successfully translate to human-virtual agent interaction in a full-body interaction experience for the teaching of social skills. Bhattacharya et al. (Bhattacharya et al. 2015) also presented research using Microsoft Kinect in a classroom setting to promote engagement with peers and social behaviors in children with ASD.

2.5 Interdisciplinary Approach

In this chapter we have shown the potentials of ICT for developing systems for individuals with ASD. In the following chapters we will introduce the three research projects that have defined this thesis.

We focused our research mainly in full-body interaction. We believe it has unique potentials as a digital medium compared to other interaction approaches. We have seen that the cognitive underpinnings of this interaction paradigm seem to suggest that EI might be more suitable for the development of virtual environments aimed at the learning of different skills. As we are exploring the advantages of EI for the learning and practicing of social communication behaviors, we believe that this media is perfect for developing intervention and therapy systems. Moreover, full-body interaction technologies allow for a more uninhibited setting, by the development of interfaces that are more natural and less restrictive for the users. As a consequence we can develop systems which go beyond fine motor sensory activity, allowing users to actively engage with the environment with their whole body.

We have also seen that literature suggest that ICT approaches might serve as more comfortable scenarios for individuals with ASD. This is given because ICT can be a comfortable place for children with ASD where scaffold complex scenarios to put into practice different abilities. Moreover, research suggests individuals with ASD show an affinity towards these approaches.

Given all these premises, we present our research as we have faced each one of the projects. First we start each chapter by explaining and framing which challenges and goals focuses each one of the projects, followed with the technology we would use. This is a necessary step for then analyzing which are the potentialities of the medium and decide the final technological approach. Once we have the technology, we design the interaction mechanics given the technology affordances and the project goals. As interaction designers it is our responsability to properly understand the interactive medium and how it best suits the research objectives. We follow with the final design of the system and its development. Then we present the evaluation and the analysis of the data and results. By explaining both the design and development, we believe it is then easier to interpret and understand the conclusions and discussion we present. We would like to clarify that our systems must be understood as a whole interactive experience, being a combination of interaction design, content design and technology.

Chapter 3

Full-body interaction for Music Therapy

In this chapter, we introduce the first full-body interaction environment we designed, implemented and evaluated to explore the potentialities of the EI media for developing solutions for motivating user's engagement and activity, and fostering social attitudes while playing. The following project focuses on the limited interests and repetitive behaviors characteristic of ASD described in Section 2.1 and music therapy principles (Section 2.1.2). The requirements specification and design of this project was mainly influenced by the MEDIATE project (Parés et al.).

SIIMTA (the acronym for "Real-Time Full-Body Interaction System and Music Therapy for people with disabilities or disorders such as Autism" in Catalan) is a full-body interaction environment MT tool for children with severe ASD. The project started in 2007 when the Tekhnikós Foundation contacted Professor Narcís Parés because they wanted to explore the possibilities full-body interaction media could offer to MT. SIIMTA was designed and developed in 2008 between the collaboration of the UPF and the Tekhnikós Fundation as my bachelor final project.

Tekhnikós is a foundation created in June 2002. It was created with the goal of fostering the research, development and deployment of new technologies

Figure 3.1: In the image a player is interacting with the virtual elements of the interactive application with his body.

for therapy for individuals with different conditions and disorders. One of their research lines is “Interacció” (Interaction in Catalan), which is focused on applying new technologies for improving HCI for people with special needs such as Autism. Their research is also mainly focused on MT. Both their interest in new technologies and music therapy served as the catalysts for motivating them to explore new media as means to develop tools for therapy.

Tekhnikós Foundation discovered full-body interaction media when they saw at an exhibition the installation named “Fullaraca” (an accumulation of fallen leaves in Catalan) based on a prototype developed as part of the MEDIATE project by the the former research group of Prof. Narcis Pars (Figure 3.1).

"Fullaraca" was a full-body interaction game that proposed the user to move an amount of particles by the interaction metaphor of air currents created through gesticulation (Parés et al., a, page 6). The virtual environment was populated by a large amount of pixels with brown and green colors, simulating the leaves in autumn. When the user did upward and lateral movements, the virtual objects would react to the movement and direction, flying around and falling again to the floor. Furthermore, the system would be keeping track of users' activity, and if they adopted a passive attitude towards the game, this would display different behaviors. This behaviors were aimed at keeping user's interest and foster their engagement.

3.1 Goals & Requirements

Music therapy specialists from Tekhnikós Foundation reported that when doing therapy sessions, they observed a tendency of patients losing interest on the sessions, thus hindering the outcomes of therapy. This could be in consonance with the limited interests individuals with ASD tend to display commented in Section 2.1.1, which may lead them to not like the sessions they must engage with, unless they are harmonized to their liking. After discovering "Fullaraca", they though that combining both their MT knowledge with more natural interactions, thanks to full-body interaction media, it could be interesting to develop a system that would make more motivating and dynamic the therapist sessions with their users. Thus, having a tool that would make MT more stimulating and engaging for patients would lead to a better outcome of the therapy process.

Moreover, they thought that full-body interactive media would be also a really good approach to counter the problems related to deficits with fine and gross motor skills characteristic in individuals with ASD, which might even lead to a loss of their capacities as they grow older. Their reasoning was that by developing a tool that would need and motivate whole body movement, patients would have the chance to put into practice motor skills while doing MT sessions.

Given these ideas, when they contacted us their main idea was to add to "Fullaraca" some audio feedback to user's input. The addition of sound would be based on dividing the interaction space into a matrix of cells, in which depending on the amount of particles being located within that cell a sound would play. The therapists would be able to define the sounds for each cell, and the trigger conditions for the sound.

During the first meeting, the idea of using "Fullaraca" was quickly discarded because the visual feedback had too much randomness. This haphazardness of the virtual objects was seen challenging and contradictory to the fondness individuals with ASD have towards sameness, repetitiveness and predictability.

After a series of meetings between Tekhnikós specialists and our research group, between all stakeholders we specified that we would have to develop a new system that would keep the serendipitous interaction "Fullaraca" displayed, but offering a more discrete and predictable virtual content. The system would have to keep the interactions "Fullaraca" fostered, whole body gesticulations to move the virtual objects. Finally, the system had to control user's sessions and be fully configurable, both for the sound space and for its content, so the application could be personalized for each child.

3.2 Interaction Design

During the meetings with Tekhnikós Foundation we decided that the users had to be motivated and engaged because of the interaction itself rather than the application content. This decision was taken from the previous knowledge acquired with the design of MEDIATE: "Therefore [...] the interaction had to be based on very clear action-reaction situations and probably rely on full-body interaction" (Parés et al., p.3). The system had to react to the users' movements promoting the user's curiosity to interact with the system.

Focusing on the interaction rather than the content was a decision also influenced by the limited imaginative play common on people with ASD.

Moreover, as autistic people tend to have a limited and stereotyped pattern of behavior, having a system based on clear action-reaction, it could be more motivating to children to adopt new behaviors suggested by the interactions defined in the system that would have not adopted otherwise.

It must be noted that most Tekhnikós Foundation therapists did not have a formal psychology nor music therapy background, but mostly were musics who applied their abilities for doing MT with children with different conditions. Thus, their approach to MT was more based on their own experience than in formal research knowledge. This posed a challenge when defining the requirements of the system as a MT experience.

Nonetheless, the other concept that would inform the interaction design for SIIMTA was the "sound hysteresis". In the audio domain hysteresis refers to implementing a sound gate through two thresholds to achieve smoother results given the fluctuations typically associated to sound signals. But for the Foundation, given their more personal experience based knowledge, the concept of sound hysteresis was one of associating movement and sound. For this system they proposed to make a sound space design where major and minor chords would match to ascending and descending movements respectively. This interaction structure would serve as the "working frame" for the musical structure upon which children with ASD would be able to build communication as we have seen in Section 2.1.2.

We decided that the interaction would be based on ascending and descending movements by the users, which would be replied by the virtual objects in the virtual environment by ascending and descending movements. The virtual objects would be then divided into columns, making it easier for users to control the virtual objects compared to "Fullaraca".

During the years of MT sessions, specialists from the foundation had created a big database of recorded sounds both collected from different digital resources, and recorded by themselves. Having prerecorded sounds lead to the idea of having a discrete sound domain, rather than working with a procedural generation of the sound stimuli.

Thus, the virtual environment would be divided in columns, with each having their own specific sound quality, and each column in cells, so different chords could be assigned to different heights. For each cell, therapist had to be able to configure two different sounds which would be triggered depending whether particles were moving on ascending or descending direction. Defining a grid where for each cell a sound could be configured would allow the foundation to easily use their sound database. Moreover it would make easier the configuration of the system for the therapist. Finally, having a discrete sound domain was thought to make it also easier for the user to understand the relation between input, visual stimuli and sound stimuli.

3.3 Design & Development

The system design followed a strategy proposed in 2001 called Interaction-driven design (Parés and Parés 2001). The interaction-driven strategy proposed by Pares and Pares focuses on the user's interaction and the physical interfaces to capture them. Once specified the interaction, the design process derives to the development of the topic and content of the application. This design paradigm really suited the development of SIIMTA, as from the initial idea, all visual content and feedback was stripped out, just to maintain the interaction principles.

A part from the decision of making the interaction more salient than the content itself, explained in the previous Section 3.2, other considerations were taken into account for when designing the application content. From MEDIATE's experience, we thought that to avoid any kind of adverse reaction of users towards the application content, we would use geometric figures as visual representations. An example would be the following: Imagine the visuals display the image of a dog. This element could be interpreted contentwise by the user and could generate a rejection (Parés et al.).

We also took into consideration the lack of symbolic play that children in the autistic spectrum tend to show (Davis et al., 1999, p.164) for content

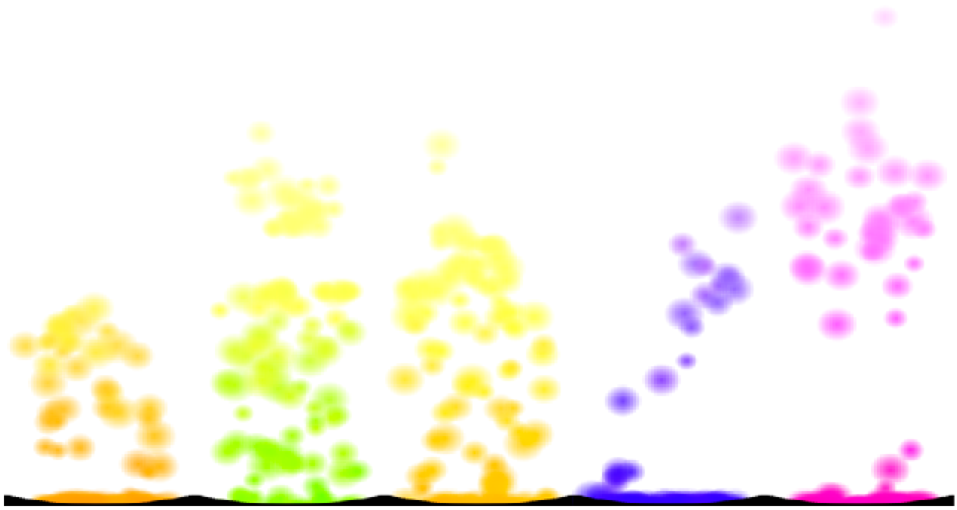

Figure 3.2: Image of the final aesthetics of the interactive system running.

design. Therefore we finally specified that the digital elements of the virtual environment would be simple geometric shapes.

For the final design of the virtual elements, we chose to use a circle shape with a fade to transparent in its surrounding margin. This way the particles systems that the user would interact with had a final look close to a viscose liquid, thanks to the blending between particles, which gave the visuals a really natural but abstract feeling. The effect is visible in figure 3.2.

After a series of prototypes, following an evolving development life-cycle, the final design was specified and implemented. We developed a system that was divided into a series of particle systems, also called springs of particles, one next to the other. The amount of columns may be specified by the therapist for each child profile. The particles can be vertically controlled by the users gesticulation. By moving parts of the body upwards or downwards

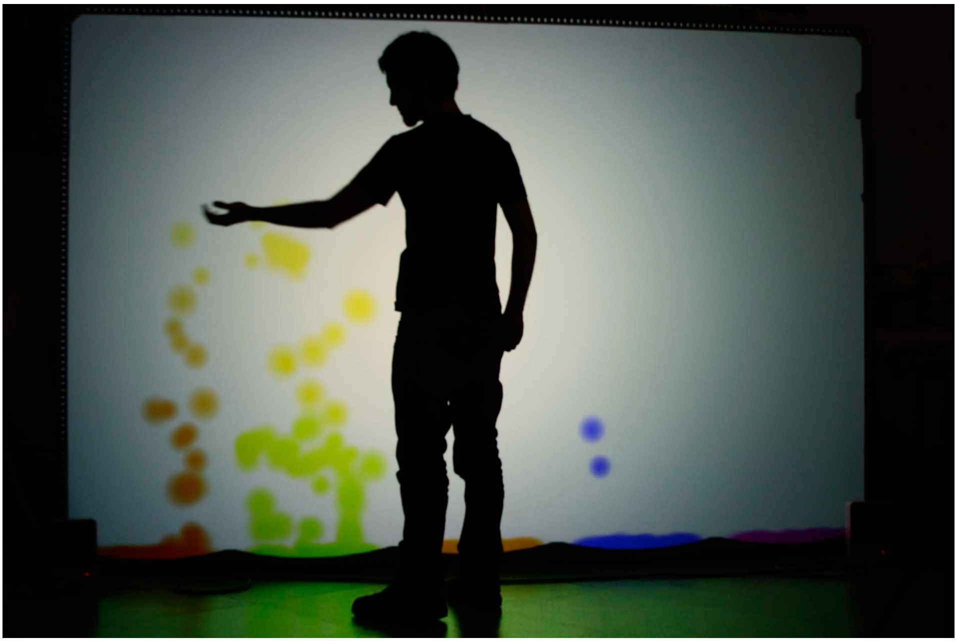

Figure 3.3: An image where a player is interacting with SIIMTA.

(such as the arms) the particles follow body direction. Particles can also be catched by the around user's silhouette while falling if the user remains still. Figure 3.3 shows a user interacting with the system.

The therapist can configure a series of cells depending on the number of rows and columns specified. In each cell the therapist can specify two sounds, each one launched depending on the overall direction of all the particles inside the cell's region. Therapists can also specify the amount of particles necessary to launch the cell's sounds. It must be noted that therapists can also configure the amount of cells for each spring, making possible the fine tuning of the interaction depending on the difficulty that they want to be achieved for each session and child.

The system also allows to configure the color of the particles, their size and speed, so therapists can configure the flow and aesthetics of the experience. The therapists and caregivers can also configure the overall volume of the system and the fade in/fade out time of played sounds, making the sound feedback more direct or indirect, and also more pleasant to each child. Finally, the system also allows for the configuration of the length of the session.

3.4 Evaluation

In 2011, as part of my Master Thesis, we evaluated the performance of SIIMTA as a therapeutic tool for conducting music therapy sessions for children with severe autism. It must be clear that the installation did not pretend to be a substitute of "regular" music therapy but that we designed it as one more support tool for music therapy specialists. One of the goals for this project was that children would feel motivated and engaged by the system during the music therapy sessions. This objective was given by Tekhnikós Foundation's music therapists reporting that normally children with ASD tended to lose motivation through the MT sessions. Thus the scope of the research was to test whether the full-body interaction system tool was capable to achieve what we designed it for or not.

For assessing the performance of SIIMTA towards the defined goals, we collaborated with "El Carrilet" special education school from Barcelona. The school, founded in 1974, works with children with ASD applying different therapies, such as play and music therapy.

The evaluation of SIIMTA was aimed at observing children's motivation and exploration through repeated music therapy sessions while playing with the installation. We decided to observe if full-body interaction and visual stimuli would foster exploration within the experience of music therapy for low functioning children with severe autism. Actually this was the original scope for developing such a tool.

3.4.1 Hypotheses

The idea of exploration was finally translated as the diversity and spatial dispersion of children activity within the installation. The hypothesis was defined through a series of meetings with "El Carillet" music therapists and psychologists. We took into account that this was the first time the installation was being really used as a therapy tool.

The null hypothesis was: Full-body interaction and visual stimuli will not foster children's activity dispersion through sessions in time.

The first hypothesis was: Full-body interaction and visual stimuli will foster children's activity dispersion through sessions in time.

Thus what was desired to observe was if the children would spatially disperse their activity through repeated sessions in time. As they discover how the application works and the sounds that are hidden in the application we expected that their activity would be broader over the interaction space.

The system analysis focused on:

- The qualitative data gathered by tests answered by the therapists and caregivers
- The quantitative data collected through log files by the system during the experiments

3.4.2 Experimental Design

As we wanted to observe the activity dispersion through time, the experiment was designed as a series of sessions done through a specified period of time. Given time constraints we decided with the "El Carrilet" therapists to make a maximum of 8 sessions during a finite lapse of time that would best suit the school's calendar. We decided that each session would last 5 minutes of play for each child.

Given time constraints and school calendar, the distribution of the 8 sessions was done through three weeks, having each week separated by a resting week.

The final distribution of sessions was (given 2011's calendar):

1. First week (1th - 17th April): two sessions
2. Second week(18th - 24th April): Easter holidays
3. Third week(25th April - 1st May): three sessions
4. Fourth week(2d - 8th May): Camp holidays
5. Fifth week(9th - 15th May): three sessions

As the first week was the first contact for the children with the installation we decided to have less sessions than the two following weeks.

During each session, groups of 3 children, based on classrooms' configuration, would play individually with the system. While one of the children played, the two other peers remained wait in the room. This configuration was specified because of two reasons: First, it was the same session structure as typical therapy sessions had in "El Carrilet". During therapy sessions, specialists worked with little groups of children. Second, while one child was playing, having other children in the space was thought to offer a source of potential interaction with the peers to the child that was playing, so we could observe spontaneous interactions between children.

As stated in Section 3.3 the system was designed for being fully customizable by the music therapists. Before starting the assessment experiments we held a meeting with "El Carrilet" music therapists, psychologists and coordinator, and Tekhnikos director and lead music therapist. The system was shown to the music therapists. Thus they could get a sense of how the system worked and all its possibilities for designing the sound mapping for the experimental sessions.

Music therapists agreed on a specific mapping for all sessions that would play with sound complexity and volume vertically. The configuration would play with the type of sound depending on the horizontal position. Thus, the configuration would continue with the "sound hysteresis" concept, but rather than playing with major and minor chords, it would play with sound entropy levels.

The sound grid was divided into six columns and four rows. Each column represented a different played instrument or natural sound. The first half of the columns where melodies played by different instruments or singed. The other half where natural sounds like laughter, rain and birds. With this configuration the music therapists tried to emulate a possible configuration for real ongoing therapy with the installation. This configuration was planed as a way to observe children preferences of sound typology, and if different entropy levels would foster user's exploration.

The other decision that was taken was to map intensity and complexity of the sound to the particles position. The metaphor was that the higher the particles rised, the louder and more complex the sound. For each type of sound two melodies or samples were recorder by the Tekhnikós lead music therapist. Both sounds were duplicated and changed in volume, so the final configuration was:

1. First row: less intense sound with "low" volume. In the original sound design, one of the columns was rain, so the sound was soft rain.

2. Second row: the same sound as the first row, but higher volume. Following the example, the sound played was the same but with a higher volume, giving the sensation of more heavy rain.

3. Third row: the sample or melody changes to one with higher complexity, but the volume is the same as the previous (lower) row. Keeping with the example of the rain column, now the sound was of a thunderstorm with distant thunders.

4. Fourth row: the sample or melody is kept from the third row, but the volume is increased to its highest level. The last sound for rain was the same as previous one (third row) but with a higher volume, making it sound as an intense thunderstorm.

3.4.3 Participants

As the experiment was to observe spatial activity dispersion in children with severe autism, we needed to access to a population of children with a severe Autism diagnosis, the population “El Carrilet” works with.

The population for the experiments was composed of 32 children in the low functional autism spectrum. All the children were diagnosed with the ADOS test Lord et al. 2000. All of the participants were diagnosed with Model 1 or 2 which take the ability to walk as the minimum developmental requirement. This modules are also used for diagnosing children who don’t have any verbal communication capability.

The gender distribution was 24 boys and 8 girls giving a ratio of 3 boys per every girl. Although this is not exactly the same as Christensen et al. 2016 defines, it is similar to research on gender distribution, such as Steffenburg and Gillberg (Steffenburg and Gillberg 1986).

3.4.4 Methods

Data gathering

For gathering data from children’s activity, a questionnaire was developed alongside specialists both from Tekhnikós Foundation and “El Carrilet” special education center. The questionnaire consisted on 5 likert-scale questions, with possibility to add comments, for therapist and caregivers. The questions were focused on gathering therapists and caregivers observations of children behavior during sessions, as it was valuable information given the previous experience of the professionals with the children (taken as baseline).

The five scaled questions were:

1. Previous motivation of the child before the session when being informed that he or she is going to play with the application.

2. Demands or joint attention with respect to the adults present in the session. How many times has the user asked for help or interacted through the therapists or caregivers body (for example taking them to the screen and waving their arm to interact with the system particles).

3. How much does the child interact with the system. Give adults perception of how much the child has been exploring and using the interaction.

4. How much has the child diversified the interaction compared to the last session.

5. Does the child imitate in any way the previous interaction?

All five questions were planned as questions that the higher the score given by the observer, the better for the purpose of the system.

A part from the questionnaires, the application would also record some data. The system saved for each session the following:

1. Sound log: The system created a log that saved every time a sound was triggered, which sound was, the cell it belonged to and the timestamps of the instant it was launched. The log also saved the instant a sound stopped being played, saving also which sound it was, the cell and the timestamps.

2. Video of the child silhouette: a video that saved all the silhouette frames during a session. It must be noted that it does not record directly what was captured by the camera. What it recorded was the silhouette obtained by the background subtraction done by the artificial vision system, which would be used as user's input.

Data operationalization

For extracting valuable information of these data a series of operationalizations were designed and applied to the recollected data:

1. Questionnaire scales: as stated before, the questionnaires were designed according to the following: the higher the scores given for each question, the better overall score. So once all questionnaires had been answered, for each session a final score was computed by summing all the scores for each answered question.

2. Sound log: for retrieving useful information of the sound log, an operationalization was defined to get an score related to what could be considered the spatial dispersion of childs activity. For each sound a weight is given depending on its vertical position. The higher the sound row, the higher the weight assigned to it. The weights were specified in a linear mode assigning to the first (or lowest) row a value of 1 while the last (or highest) row a value of 4. Also a series of multipliers were defined to give a bonus every time the child changed the column. These multipliers decreased linearly their value every time the column change was repeated.

3. Silhouette video: we wanted to focus mainly on the overall activity of the child, so the first process applied to the video was to convert it into movement video. This is achieved by subtracting each frame from the previous one. The video is then converted into a series of frames where lighten pixels represent the physical movement of the user in front of the camera. The next step was to add all these frames into a unique image, thus having a final image were all movement was accumulated. This final image was used to generate a series of heatmaps for each session to have visual feedback of child activity. The maximum value for normalizing the data was found by searching through all accumulated values of all post processed silhouette videos. See Figure 3.5. This way, the maximum value found was used as the maximum practical accumulated movement children could achieve during sessions. We chose this approach as we used the real data registered for the overall normalization of the accumulated movement. Once we had the heatmap, the number of pixels was summed to a final two dimension array. This array would show the amount of vertical move-

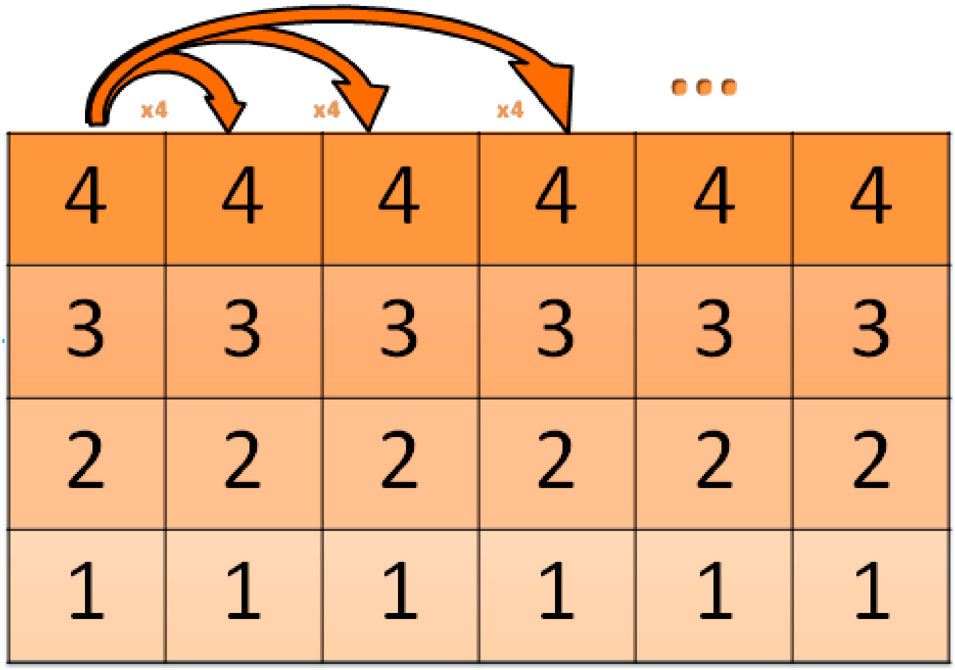

Figure 3.4: Diagram that shows the distribution of weights and multipliers for the sound log operationalization.

ment accumulated in the x axis. We took this decision because we mainly wanted to observe users activity dispersion, mainly characterized by moving from one to another column while still searching some continuous activity in each column. Finally a density operation was applied to this two dimensional array (x representing the width of the screen and each value the amount of movement) to get an index that could reflect the overall dispersion of the childs activity during the session.

Session guidelines

For each session the system would record a log of each sound triggered by the players. This way, we could calculate the amount of different sounds

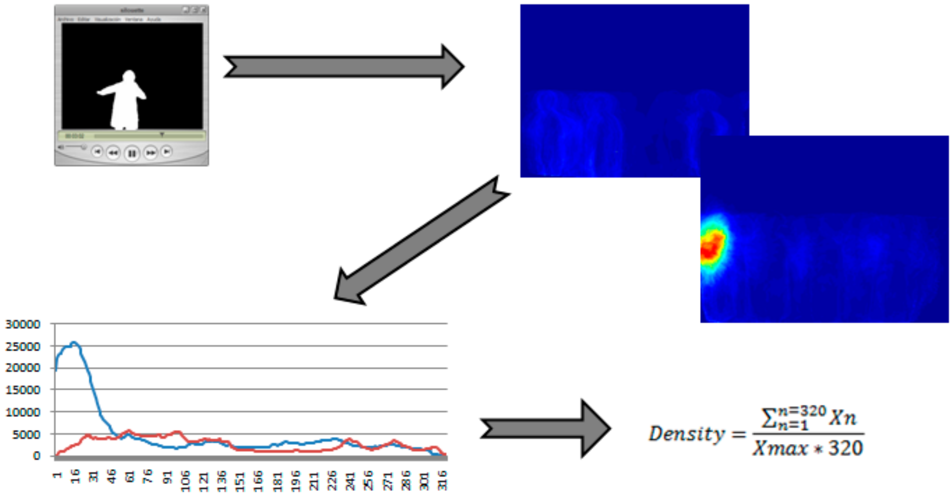

Figure 3.5: Scheme showing the process for subtracting movement density from silhouette videos.

played. And the higher their position, the "volition" put on triggering that sound.

For running the experiments, we specified a series of directives for therapists and caregivers for the first and the successive sessions.

For the first session:

1. If after 3 minutes the child does nothing one of the therapists must go to left side of the screen and wave upwards his arm until the sound from the first row of the first column is launched. It must be understood that the first row means the one closest to the floor.

2. If the child wants to stop playing and leave the room there shouldn't be any type of restriction.

After the first session the subsequent directives were:

1. If the child goes behind the screen to interact with system elements

such as the camera, the lights, speakers or projector, one of the therapists or caregivers must take the child back to the front of the screen.

2. If the child goes to one of the therapists or caregivers: passively the adult will go with the child and do what is requested.

3. If the child wants to stop playing he or she should be allowed but without leaving the room.

In each session one of the therapists or caregivers would have to take notes in the questionnaires they had during and after the each session. After the sessions with the three children they had also to rate each question with a scale from 1 to 5 if possible.

3.4.5 Procedure

The system was set up in a multipurpose space from "El Carrilet" reserved for music therapy sessions, group sessions and meetings (Figure 3.6). Each session consisted of up to three children entering at the same time in the room to do 5 minutes sessions per child. Thus it took around 15+ minutes per session.

First of all the system was always checked before the children entered the room. The children sat in front of the screen waiting for their turn. Two therapists or caregivers entered with the children. There was also a psychiatrist waiting inside for taking observations. The order of the children was fully randomized between the groups. Thus every session a different child started playing with the application.

While children were waiting, one of the two therapists or caregivers in the room selected the children's session in the system and launched the interactive application. At that moment the child was requested to stand in front of the screen and was allowed to start playing with the particle systems freely. No indication was given on how the application worked and it was fully left to the child's motivation to discover how it actually worked. After

Figure 3.6: Photography of the system installed in the multipurpose space from “El Carrilet” special education center.

five minutes, the application automatically faded into black to announce the interaction had finished. Then the child had to sit at the back of the room and the process was repeated for the other two children.

After each group session finished, therapists and caregivers filled out the questionnaires for each child. At the end of each day of experiments, registered data was collected.

It is important to make clear that although we recruited 32 participants, the final population ended up being much smaller. First, some children dropped out for different reasons such as having other activities or being sick, and did not complete the whole 8 sessions. Second, during some sessions the guidelines were not followed properly by the therapists or caregivers, which lead to recording and interaction issues during the sessions. The tracking system was sensible to calibration, making it a little bit difficult to set up the session for a unique caregiver and three children with self motor regulation

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
S1	,197	8	,200*	,860	8	,120
S2	,198	8	,200*	,862	8	,126
S3	,272	8	,083	,887	8	,220
S4	,139	8	,200*	,976	8	,941
S5	,242	8	,186	,875	8	,169
S6	,129	8	,200*	,973	8	,922
S7	,188	8	,200*	,933	8	,548
S8	,177	8	,200*	,973	8	,920

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Figure 3.7: Shapiro-Wilks' normality test for movement density values.

challenges (Gabriels et al. 2005; Johnson and Myers 2007). Given these problems, the final population who did all 8 sessions without any problems was only 8 children with ASD out of 32 recruited.

3.5 Results

To analyze the results of the movement density first of all we checked if the data was normally distributed with a Shapiro-Wilks test (Figure 3.7).

As Shapiro-Wilk results show, the data is normally distributed. Shapiro-Wilks normality test is more indicated for small samples than Kolmogorov-Smirnov, thus with a final population of just 8 subjects, we decided to use Shapiro-Wilks results.

As data was normally distributed we applied a repeated measures procedure to see if there was any statistical significant difference in the data (Figure 3.8).

As results show there was no significant difference between the sessions, so no valid conclusions can be extracted from the movement density data

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
Sessions	Pillai's Trace	,998	64,807[a]	7,000	1,000	,095
	Wilks' Lambda	,002	64,807[a]	7,000	1,000	,095
	Hotelling's Trace	453,646	64,807[a]	7,000	1,000	,095
	Roy's Largest Root	453,646	64,807[a]	7,000	1,000	,095

a. Exact statistic

b. Design: Intercept
Within Subjects Design: Sessions

Figure 3.8: Wilks' Lambda test results for movement density.

the system collected. Moreover, if we observe the boxplot for the movement density operationalization, we can see visually that there is no clear tendency in the data through sessions (Figure 3.9).

The same procedure was followed for the sound logs. First of all the normality of the data was checked using Shapiro-Wilks normality test (Figure 3.10).

Results show that for some sessions the data was not normally distributed. Thus, to check if there was any statistically significant difference between the scores of the audio logs operationalization, we used the Friedmans test for non normal distributed data (Figure 3.11).

In the boxplot we can see there is an ascending coefficient tendency (Figure 3.12). This means that at least there was an overall tendency to increase the diversity of sounds played through sessions

Post-hoc tests were done in order to see if there was truly a statistical significance between sessions. The following figures (from Figure 3.13 to 3.20) show the post-hoc tests applied between all the sessions.

In the post-hoc tests we saw there was no significant difference between the sessions. Despite this lack of significance in post-hoc pairwise tests, results show a tendency to significance that must be taken into account given the low population we finished analyzing.

Finally, we analyzed the data from the questionnaires. As an overall score

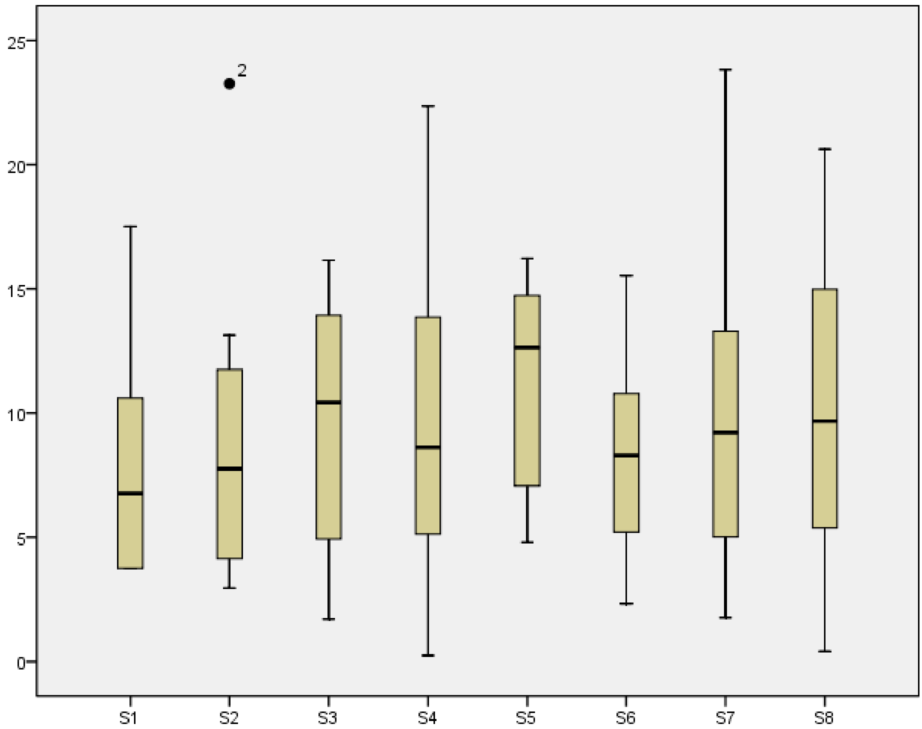

Figure 3.9: Boxplots for movement density during the eight sessions.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
S1	,207	8	,200*	,908	8	,342
S2	,169	8	,200*	,911	8	,360
S3	,329	8	,011	,764	8	,012
S4	,214	8	,200*	,917	8	,405
S5	,430	8	,000	,577	8	,000
S6	,172	8	,200*	,944	8	,652
S7	,312	8	,021	,809	8	,036
S8	,202	8	,200*	,896	8	,265

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Figure 3.10: Shapiro-Wilks' normality test for sound logs final score values.

Test Statistics[a]

N	8
Chi-Square	18,208
df	7
Asymp. Sig.	,011

a. Friedman Test

Figure 3.11: Friedman's test for final scores obtained from audio logs through the aforementioned operationalization.

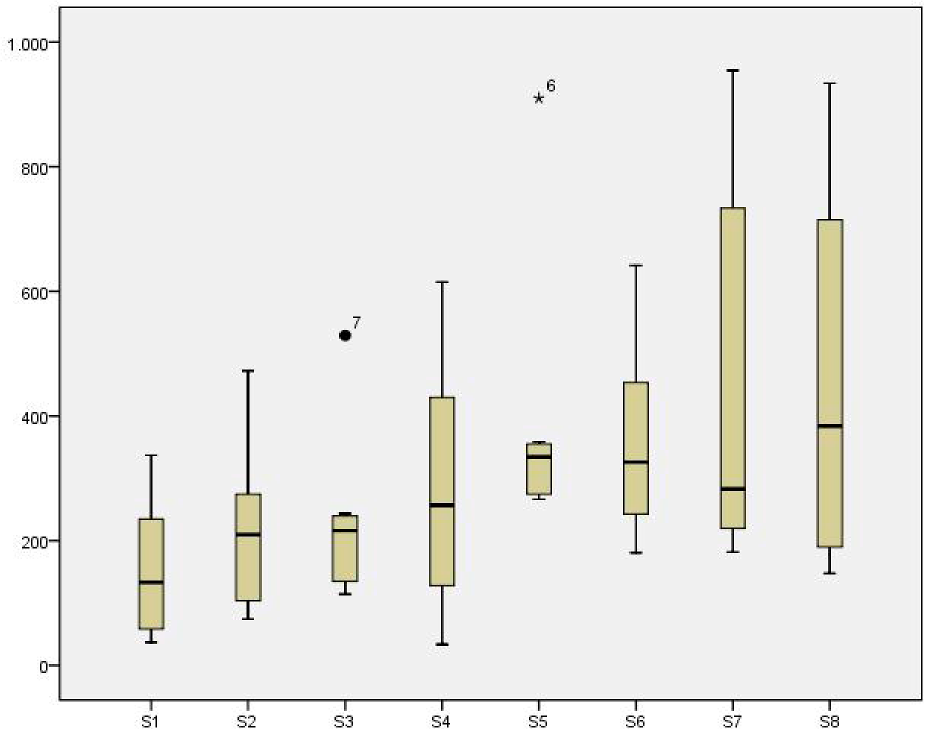

Figure 3.12: Boxplots for audio logs computed scores for each one of the eight sessions.

Test Statistics[b]

	S2 - S1	S3 - S1	S4 - S1	S5 - S1	S6 - S1	S7 - S1	S8 - S1
Z	-1,260[a]	-1,260[a]	-1,680[a]	-2,100[a]	-2,521[a]	-2,100[a]	-1,960[a]
Asymp. Sig. (2-tailed)	,208	,208	,093	,036	,012	,036	,050

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure 3.13: 2 sample post-hoc test for audio logs for Session 1.

Test Statistics[d]

	S1 - S2	S3 - S2	S4 - S2	S5 - S2	S6 - S2	S7 - S2	S8 - S2
Z	-1,260[a]	,000[b]	-,700[c]	-2,240[c]	-2,100[c]	-1,960[c]	-2,240[c]
Asymp. Sig. (2-tailed)	,208	1,000	,484	,025	,036	,050	,025

a. Based on positive ranks.

b. The sum of negative ranks equals the sum of positive ranks.

c. Based on negative ranks.

d. Wilcoxon Signed Ranks Test

Figure 3.14: 2 sample post-hoc test for audio logs for Session 2.

Test Statistics[d]

	S1 - S3	S2 - S3	S4 - S3	S5 - S3	S6 - S3	S7 - S3	S8 - S3
Z	-1,260[a]	,000[b]	-,700[c]	-1,680[c]	-1,540[c]	-1,680[c]	-1,820[c]
Asymp. Sig. (2-tailed)	,208	1,000	,484	,093	,123	,093	,069

a. Based on positive ranks.

b. The sum of negative ranks equals the sum of positive ranks.

c. Based on negative ranks.

d. Wilcoxon Signed Ranks Test

Figure 3.15: 2 sample post-hoc test for audio logs for Session 3.

Test Statistics[c]

	S1 - S4	S2 - S4	S3 - S4	S5 - S4	S6 - S4	S7 - S4	S8 - S4
Z	-1,680[a]	-,700[a]	-,700[a]	-1,260[b]	-1,120[b]	-1,820[b]	-2,240[b]
Asymp. Sig. (2-tailed)	,093	,484	,484	,208	,263	,069	,025

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Figure 3.16: 2 sample post-hoc test for audio logs for Session 4.

Test Statistics[c]

	S1 - S5	S2 - S5	S3 - S5	S4 - S5	S6 - S5	S7 - S5	S8 - S5
Z	-2,100[a]	-2,240[a]	-1,680[a]	-1,260[a]	-,280[a]	-,420[a]	-,700[b]
Asymp. Sig. (2-tailed)	,036	,025	,093	,208	,779	,674	,484

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Figure 3.17: 2 sample post-hoc test for audio logs for Session 5.

Test Statistics[c]

	S6 - S1	S6 - S2	S6 - S3	S6 - S4	S6 - S5	S7 - S6	S8 - S6
Z	-2,521[a]	-2,100[a]	-1,540[a]	-1,120[a]	-,280[b]	-,700[a]	-1,120[a]
Asymp. Sig. (2-tailed)	,012	,036	,123	,263	,779	,484	,263

a. Based on negative ranks.

b. Based on positive ranks.

c. Wilcoxon Signed Ranks Test

Figure 3.18: 2 sample post-hoc test for audio logs for Session 6.

Test Statistics[c]

	S7 - S1	S7 - S2	S7 - S3	S7 - S4	S7 - S5	S7 - S6	S8 - S7
Z	-2,100[a]	-1,960[a]	-1,680[a]	-1,820[a]	-,420[b]	-,700[a]	-,140[a]
Asymp. Sig. (2-tailed)	,036	,050	,093	,069	,674	,484	,889

a. Based on negative ranks.

b. Based on positive ranks.

c. Wilcoxon Signed Ranks Test

Figure 3.19: 2 sample post-hoc test for audio logs for Session 7.

Test Statistics[b]

	S8 - S1	S8 - S2	S8 - S3	S8 - S4	S8 - S5	S8 - S6	S8 - S7
Z	-1,960[a]	-2,240[a]	-1,820[a]	-2,240[a]	-,700[a]	-1,120[a]	-,140[a]
Asymp. Sig. (2-tailed)	,050	,025	,069	,025	,484	,263	,889

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure 3.20: 2 sample post-hoc test for audio logs for Session 8.

Test Statistics[a]

N	8
Chi-Square	27,221
df	7
Asymp. Sig.	,001

a. Friedman Test

Figure 3.21: Friedman's test for responses to the question "How much does the child interact with the installation?".

(adding all the results from all questions) we did not find any statistically significant difference between results from different sessions. Nonetheless we analyzed individually the results from question 3: "How much does the child interact with the installation?". This question directly related to what we were trying to analyze, the amount of activity observers perceived from children when interacting with the system per session. The results were quite close to the ones from the sound logs.

First of all we tested if there was any significance in the results applying Friedmans test, as data was not normally distributed (Figure 3.21).

We observed there was a strong statistical significance. Observing the boxplot for the question 3 of the questionnaires, we can also observe there is an ascending tendency in the grading of the interaction experience (Figure 3.22).

But again is just with statistical analysis that we can fully understand the information within the data being analyzed. We applied 2 sampled post-hoc tests to the data from question number 3 to see if there was a real significance between the sessions. There was no significance between sessions in the post-hoc. Again results showed a tendency to significance but it would have been better to have a larger experiment.

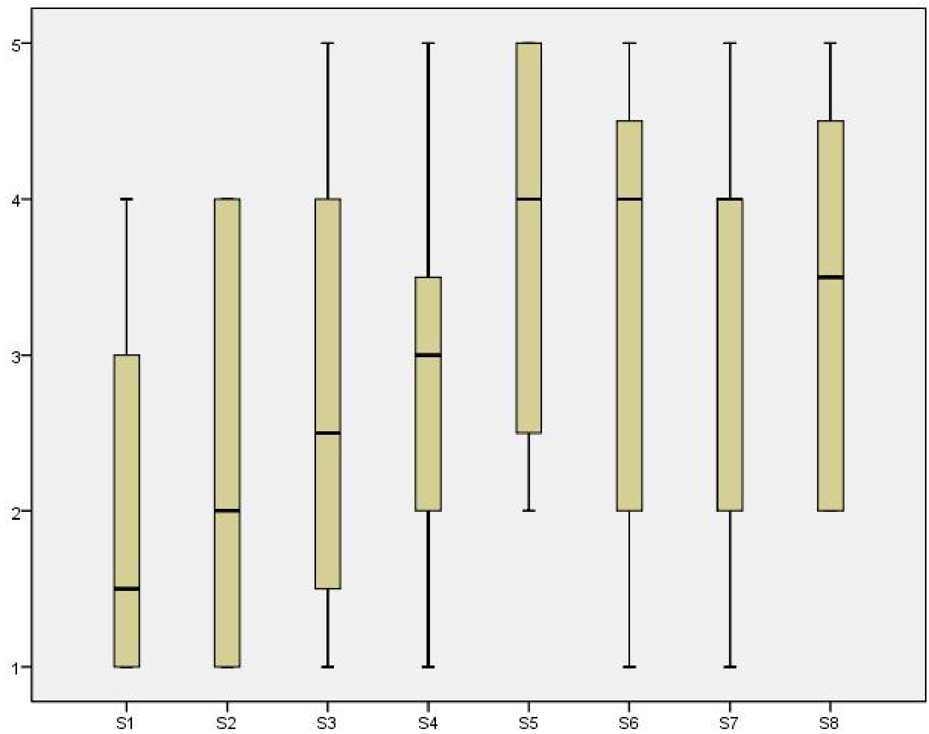

Figure 3.22: Boxplots for responses to the question "How much does the child interact with the installation?".

3.6 Conclusions & Discussion

Once all data has been analyzed we cannot reject the Null Hypothesis. Even though statistical analysis show partly promising results.

In one hand we have results from movement density. The values obtained by the statistical analysis are far than close to support the First Hypothesis. There can be some possible explanations and solutions to this issue:

- The operationalization specified for the videos was not correct to fully subtract the desired information from the recordings. Further research must be done regarding extracting valuable data from the videos.

- A codification sheet could be developed to analyze the videos by external people. The coding wouldnt focus on expression but on gesticulation.
- The normalization factor applied to the videos was based on the maximum achieved by the children during the overall experiment. Another solution could be searching for a baseline based on non-autistic users.
- There were not enough subjects to have a sample big enough for having significant results.

In the other hand therapists observations, and operationalizations applied to sound logs, are close to reject the Null Hypothesis. The results aren't significant enough for supporting the First Hypothesis but converge to a significance. Values are close enough to see the necessity of testing again the system as a therapeutic tool for assessing music therapy.

The results from question number 3 and the sound logs motivate us for further research in this direction. Despite the positive results we must do some autocriticism. The operationalization applied to sound logs must be revised again and tested with non-autistic people. A series of sessions with people being asked to follow some directives could be interesting to see the potential of the operationalization. Also regarding the questionnaires a refined version could be tested and better explained to therapists. Furthermore during experiments new tests could be handled to external observers less biased by previous experience with the children.

To sum up the results are good enough to try to repeat the experiment with a bigger population and a broader time window. As it is an experiment that tries to observe children behavior through time it could be interesting to have more time between sessions.

Chapter 4

A Kinect-based game for learning social skills

Publications

This chapter is based on the following publications:

- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Maria Angeles Mairena, Amaia Hervs, Narcis Pares (2014) Participatory design strategies to enhance the creative contribution of children with special needs. IDC '14: Proceedings of the 2014 conference on Interaction design and children. pp. 85-94. ISBN: 978-1-4503-2272-0 doi: 10.1145/2593968.2593981

- Joan Mora-Guiard, Laura Malinverni, Narcis Pares. (2014) Narrative-based elicitation: orchestrating contributions from experts and children. CHI EA '14: CHI '14 Extended Abstracts on Human Factors in Computing Systems. doi: 10.1145/2559206.2581292

- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Amaia Hervas, Narcis Pares (2014) Picos Adventure: A Kinect Game to Promote Social Initiation in Children with Autism Spectrum Disorder. In the proceedings of the ITASD 2014 2nd International Conference on Innovative Technologies for Autism, At Paris, France.

- Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, Lilia Valero, Amaia Hervas, Narcis Pares (In press) An inclusive design approach for developing video games for children with Autism Spectrum Disorder. Journal of Computers in Human Behavior.
  doi: 10.1016/j.chb.2016.01.018

- Joan Mora-Guaird, Laura Malinverni, Narcis Pares (To be submitted) Designing a kinect-based a multi-user videogame for fostering social behaviors in children with ASD.

- Joan Mora-Guiard, Laura Malinverni, Maria Angeles de Mairena, Amaia Hervas, Narcis Pares (To be submitted) Pico's Adventure: an interactive experience to promote social initiation in children with autism.

In this chapter, we present the research we did for the European Commission research project "Motion-based adaptable playful learning experiences for children with motor and intellectual disabilities" (M4ALL) (Project n 531219-LLP-1-2012-1-IT-KA3-KA3MP). The project was funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. The research project was a joint venture between the Centro Benedetta d'Intino, University Politecnico di Milano, Univeristy of Piraeus Research Center, Eindhoven University of Technology and Universitat Pompeu Fabra.

M4ALL was an European project aimed towards developing a series of motion-based playful experiences for children with intellectual and motor disabilities. One of the conditions of the project was that all M4ALL educational games had to be developed using affordable and widespread interactive technology. In this context, our objective was to develop a Microsoft Kinect based game for children with Autism Spectrum Disorders

(ASD), a population we selected given our previous knowledge in the field. The project lasted for 24 months; started on 01/12/2012 and ended on 30/11/2014.

For our participation in this venture we developed the “Pico’s Adventure” interactive experience, a game based on the Microsoft Kinect sensor for children with ASD aimed at promoting skills related with social initiation and scaffolding social interaction between ASD children and other people. Fostering social initiation was understood as the promotion of behaviors such as approaching and looking for others, trying to start social communication and producing any verbal or gestural behavior for communicative goals.

In this project we collaborated with the UETD: Unidad Especializada en Trastorno del Desarrollo (UETD) of Hospital Sant Joan de Déu in Barcelona (Specialized Unit on Developmental Disorders). The Sant Joan de Déu Hospital is a university hospital that is renowned in all of Spain, as well as in Europe, as a center at the forefront of health for children, both in clinic daily practice and in research. The UETD is specialized in Autism and is composed by psychiatrists, psychologists, pedagogues and neurologists. It has a solid clinic practice experience as they diagnose most of the ASD cases in Barcelona and surroundings, they provide initial support to families and children that have been diagnosed as ASD, they redirect these children to special education centers depending on their place of residence and their specific needs, and they follow up the evolution of the children. Therefore they could help us in correctly defining the demography for our project as well as getting in touch with the end users. On the other hand the UETD has also a solid research activity in genetic, neurology, psychiatric, psychological and pedagogical aspects of ASD. Hence they could also provide us with very good support in defining the requirements for the motion-based games, in defining the study procedures and methods, in deciding on which are the best evaluation methods and in the evaluation of the data gathered and production of final results.

The collaboration with the UETD was defined at three main levels:

- Providing scientific support on the Autistic Spectrum Disorder and helping to define guidelines for design and evaluation of the application.
- Making tests and experiments feasible by providing access and logistic help with end-users
- Helping with the logistic and the organization of the workshop for evaluating the design with users as informants.

4.1 Goals & Requirements

The UETD unit from HSJD works mainly with Applied Behavioral Analysis (ABA) interventions for children with ASD. As mentioned in Section 2.1.2 ABA is based on shaping behavior and the teaching of new skills using positive reinforcement. These reinforcements are stimulus used to strengthen the desired behaviors. ABA is the most used intervention for treating children with Autism given its successful results applied at early stages of development Cebula 2012; Estes et al. 2014; Johnston et al. 2006.

One ABA intervention, previously introduced (Section 2.1.2), adopted by the specialists of HSJD is the Early Intensive Behavioral Intervention (EIBI) Lovaas Model by Dr. Ivar Lovaas Lovaas. In Lovaas Model structured EIBI is carried by applying discrete trial training of basic skills. Whenever users behave as desired, their performance is gratified with praise and reinforces, so those behaviors can later generalize to everyday environment.

As stated in the Section 2.1.2 another variation of Applied Behavioural Interventions (ABI) is the Early Start Denver Model (ESDM) by Dr. Geraldine Dawson and Dr. Sally Rogers Dawson et al. 2012. ESDM is a program designed to be applied with children ranging from 12 to 48 months old. This model involves the parents deeply in the intervention procedure, offering more naturalistic settings for therapy. In the project presented in this chapter, we did also put an special stress on embedding parents during game experience. The ESDM intervention also focuses on positive reinforcement to desired social and communication behaviors in joint activities.

As In Lovaas Model and ESDM, in Pico's Adventure we designed a series of game scenarios (i.e. sessions) where children with ASD could punt into practice specific social skills, with audiovisual reinforcements when they succeeded during gameplay.

The aforementioned collaboration with the UETD was organized around technical meetings in which we explained to the UETD the potential of the full-body interaction and provided an important number of examples and references. At the same time, the UETD provided insight on the most important aspects of ASD that could be fostered through this technology. This exchange was guided through 6 sessions of a duration between 60 and 120 minutes each. The following points were clarified during the meetings:

- We would work with mid-functioning children because often projects are directed towards high-functioning children, see Section 2.3. Focusing on mid-functioning children and not including low-functioning was a decision based on the currently improbable situation of having low-functioning children starting social interaction due to their severe disabilities.
- Research in ASD and social interaction is mostly focused on training strategies for allowing high-functioning children to learn specific social abilities. However, the experts of the UETD thought it would be advisable to take a step back when dealing with mid-functioning children. The main goal would not be teaching specific social skills, but rather making children aware that starting very elementary social interaction can greatly benefit them.
- It is well known that ASD children are very fond of audiovisual technology and interactive media, especially of videogames (Section 2.3). Hence, we defined that the potential of full-body interaction media was that of being able to introduce situations in which ASD children

could play with other users in a collocated situation. The developed experience would serve as a mediator to foster initiations of social interaction by proposing different levels of collaborative and cooperative play.

After these main pillars were founded, the two teams together undertook the definition of the specific requirements to address concrete aspects of social interaction. This process was led by sketching informal play scenarios and having the UETD experts point out elements that could be useful and those that could be left out.

The UETD also defined the target profile of users to be children with autistic spectrum disorder of 5-6 years old with medium/medium-high functionality. The selection of this target focused on promoting an early intervention treatment. Recent research findings show the fundamental importance of early diagnostic Klin et al. 2009 and intervention in children with ASD, since it leads to higher success rates Warren et al. 2011. From a developmental perspective, children at this age start to master gross and fine motor skills, which represent a fundamental aspect for fully take advantage of the possibilities offered by full-body interaction. As we have seen in Section 2.1.1, individuals with ASD show a higher tendency of deficiencies in fine and motor skills —MacDonald et al. 2014, thus it is important to develop experiences who allow them to put this newly acquired skills into practice as soon as possible.

At the same time, at this age children start to be inserted into primary school, which for an autistic child can often represent a challenging and stressful experience Bauminger-Zviely et al. 2014. Within this target age is therefore particularly important to provide children with an adequate support and treatment to work on appropriate social behaviors Russo and Koegel 1977.

Finally, as mentioned in Section 2.1, main impairments in autism are those related with the dimension of social interaction, communication and imagination. Within these, many researchers suggested that the social impairment may represent the most important deficit Roeyers 1994. Thus, it is fundamental to take into consideration behaviors related with social initiation. Even if children with autism can learn to respond to social initiations made by others, they may have major difficulties in initiating social interaction: as a result of that, social interaction may be compromised Nikopoulos and Keenan 2003. At the same time, some studies showed that when social initiation rate increases, it leads to a significant improvement in social behaviors Strain et al. 1979.

Starting from this perspective, together with the psychologists we decided to focus the main goal of the game towards promoting social initiation, understood as the promotion of behaviors such as approaching and looking for others, trying to start social communication and producing any verbal or gestural behavior for communicative goals.

In order to achieve the main goal the psychologists defined a short treatment plan based on four sessions. This treatment plan served as a fundamental starting point for the definition of requirements for design of the game, since it provided the basic structure upon which to build the gameplay. The four sessions of the treatment plan were organized through a progressive order, which main goal was to foster behaviors related with initiate a social interaction with others and collaborate with them. For this purpose sessions were organized as follows:

- 1st session : the child plays alone.
- 2nd and 3rd sessions: the child plays with one of his parents.
- 4th session: two children included in the treatment program play together.

This order was chosen to allow children to get used to the environment and the multiple different play modalities through the presence of a familiar adult and thereafter inserting the play experience with another child.

Moreover, each session had to provide situations in which a series of behaviors related with social initiation skills were addressed. These behaviors were defined, by the psychologists, as a set of objectives.

The behaviors were operationalized as follow:

1. Instrumental gestures: promote the use of gestures that allow achieving something from somebody else (i.e. make a gesture with the hand to ask somebody to come in a certain place).
2. Conventional gestures: promote the use of gestures based on sociocultural conventions (i.e: Say bye with the hand).
3. Discrimination: promote behaviors oriented at discriminating between different elements (i.e. discriminate between different fruits).
4. Reciprocity (Turn-taking): define situation that requires to respect turns during cooperative games or activities
5. Imitation: define situation that requires to imitate the actions of somebody else.
6. Initiation and answer in Joint Attention: promote behaviors that requires an attempt by the child to call the attention of the adult toward an object that nobody is touching (i.e. pointing to something).
7. Answer to Joint Attention: define situation that requires the child to direct his attention to the object that the adult is showing (i.e. showing likeable objects and wait for a joint attention answer)
8. Vocalization: define situation that requires the child to produce sounds
9. Recognition of basic emotions: define situation that requires to recognize basic emotions (happiness, fear, sadness, anger, surprise)
10. Cooperation: define situation that requires the child to build/do something together with somebody else

These behaviors represented fundamental aspects that need to be addressed within traditional treatment related with fostering social initiation. Moreover they found an appropriate support in full-body interaction, since this interaction approach, by promoting an active use of the body (Dourish 2004) and by allowing multiple players in the game, can facilitate conditions for gesturing and engaging in collaborative activities.

Another main requirement agreed with specialists from UETD was to design activities that could not be solved by the child alone but rather require the collaboration of another person. This requirement was defined in order to facilitate conditions in which the child needed to look for the help of other and start a social interaction with them to achieve their objective through desired behaviors.

To address the defined goals and requirements two therapeutic techniques, derived from ABA intervention, were implemented in the game: Modelling and Positive Reinforcements:

1. Modelling: As we have seen in Section 2.3.1 one approach that has proven to be successful for teaching a variety of skills to individuals with autism is video modelling. Video modelling is based on having the individual watch a video that shows the target behavior and then provides the conditions for the person to replicate this behavior Rayner 2010. Within the game this technique was implemented through the behavior of a virtual agent. The virtual agent was used as a friend who provided a visual model of the targeted behaviors, according to modelling technique. The use of virtual agents as visual models has been proven to be successful for teaching social skills given their structuredness, pleasant to ASD children Hopkins et al. 2011; Agarwal et al. 2012, as seen in Section 2.3.3.

2. 2) Use of Positive Reinforcements: as seen in Section 2.1.2, within ABA positive reinforcements are stimulus used to strengthen the desired behaviors Dawson et al. 2012; Lovaas. Different reinforcements

can be given to patients depending on the exercise or the user itself and its preferences. Within the game a series of positive reinforcements were added to reward the child when accomplished the targeted behavior given by different in game objectives. Positive reinforcements used in the game were: sounds effects, visual effects (i.e. fireworks), the progression in the narrative and the behavior of the virtual agent.

4.2 Interaction Design

As stated in previous Section 4.1 the main goal of our research was to promote social initiation, understood as the promotion of behaviors such as approaching and looking for others, trying to start social communication and producing any verbal or gestural behavior for communicative goals.

We have seen that in order to address this goal the psychologists defined a short treatment plan based on four sessions of 1 hour each. The sessions of the treatment defined given the amount of players presented in Section 4.1 would be organized as follow:

- 1st session: The child plays alone while the game presents a virtual agent which will pose different behavioral situations. This initial scenario will serve for the child to get use to the environment and familiarize with the virtual agent.

- 2nd and 3rd sessions: The child will play with one of his/her parents while helping the virtual agent in two different scenarios. First in the same virtual environment (so change from 1st to 2nd session is not too big), second in a new environment, virtual agent's world.

- 4th session: The child will play together with another child included in the treatment program; i.e. both children will now share the experience. They will play in the same virtual environment as 3rd session, but with a new objective.

This sequence was chosen to allow children to first get used to the environment and the virtual agent by themselves. Then the game would introduce the multiple player mode through the presence of a familiar adult with more engaging and difficult activities. Finally the play experience would be with another child (not previously met) to put into practice all the previous used social skills. Therefore, each session would provide situations in which a series of behaviors related with social initiation skills were addressed and accumulated. The sessions were based on an increasing level of complexity in the required social initiation skills defined in Section 4.1.

In order to specifically address the goals and sub goals established by the psychologists, the different objectives were mapped onto specific game mechanics addressed at fostering specific attitudes and behaviors (Tables 4.1 and 4.2). A set of mechanics based on the defined sub goals were specified, while at the same time, first initial idea for the game were sketched for giving the interaction mechanics a purpose. A deeper explanation of the elicitation of content design will be explained in Section 4.3.

4.3 Design & Development

Starting from the 4 sessions structure defined by UETD group, we decided to design a game based on four levels, corresponding to the four sessions of the treatment plan. In order to enhance the enjoyability and the playfulness of the experience, a backstory based on Aristotles 3-acts structure and Campbells monomyth, were defined to guide the gameplay (Table 4.3).

4.3.1 Participatory Design

When designing systems for people with special needs, it is important that these individuals are included as informants for the design process (Frauenberger et al. 2012). Doing so can allow for increased understanding of the requirements specific to that population. One of the most common approaches is the use of Participatory Design (PD) which involves people of the target population in the design of the technology (Ehn 1990).

	Main Goal	Objectives	Mechanics
1	Social Initiation	Instrumental gestures	The child has to do gestures to get the food for the virtual agent
		Stimuli discrimination	The virtual agent indicates some preferred food, child has to get it
		Vocalizations	The child has to vocalize to scare the antagonists that try to steal food
2	Previous + Cooperation	Instrumental gestures	The child has to do gestures to get the different pieces of the virtual agents spaceship
		Cooperation	The child has to cooperate with the adult in order to get the energy to fuel the spaceship
		Stimuli discrimination	The child has to discriminate between useful and useless energy

Table 4.1: Classification of general objectives, relative social skills and game mechanics for level 1 and level 2

Taking this into account, in order to enhance the desirability of the experience and to fit the game with user preferences we carried out five participatory design workshops with users as informants (Table 4.4). The five participatory sessions were structured by a narrative based in the use of the plot of the game that was previously defined through the meetings with the psychologists (Section 4.1). Each workshop activity was designed to form part of a larger narrative structure and to address specific design questions. Three main techniques were used to promote a feeling of narrative continuity and progression: scene cards, cliffhangers and a personalized box for each child where they could keep their contributions and rewards.

Four children selected by the psychologists, according to an adequate verbal and cognitive level of development, participated in the sessions. The goal of the workshop was to identify metaphors, visual design aspects and narrative elements that could result enjoyable to the children. At the same time, careful attention was posed in testing the comprehensibility of the

	Main Goal	Objectives	Mechanics
3	Previous + Joint Attention	Joint attention	The child calls the attention of the adult to target objects by pointing
		Cooperation	The child has to cooperate with the adult to joint their pointing gestures toward the target
		Stimuli discrimination	The child has to discriminate between target objects
4	Previous + Turn-taking	Turn-taking	The two children have to coordinate between them in order to simultaneously catch the target
		Cooperation	The two children have to cooperate between them in order to progress
		Joint Attention	The child as to call the attention of the other child towards the target objects through a pointing gesture
		Stimuli discrimination	The children have to discriminate between target objects

Table 4.2: Classification of general objectives, relative social skills and game mechanics for level 3 and level 4

	Narrative Structure	Play Mode	Environment
1	Game presentation	1 child	Forest
2	Child journey start	child + adult	Forest at night
3	Child journey continues	child + adult	Alien planet
4	Final challenge & resolution	2 children	Alien planet

Table 4.3: Translation of treatment plan into game levels and addressed social skills

Session	Scene Card	Chapter
1	Location: wood (planet Earth); day Targeted behavior: start interaction	Introducing the main character
2	Location: wood (planet Earth); day Targeted behavior: start interaction / Conflict: antagonists	Build a relation with the main character; help it
3	Location: wood (planet Earth); night Targeted behavior: start a cooperative activity with a familiar adult	Help the character to build and fuel its spaceship; travel back to its planet
4	Location: aliens planet Targeted behavior: joint attention Conflict: antagonists	Help the character to find its friend
5	Location: aliens planet Targeted behavior: turn taking Conflict: antagonists & resolution	Meeting with the friend; celebration

Table 4.4: Participatory design structure

proposed mechanics. For this purpose each session was focused on exploring the gameplay and the art of a specific level. Children were therefore invited to explore our proposal through low fidelity prototypes and propose novel possible solutions. Several co-design techniques were used such as: scaled prototype, wizard-of-oz, drawing, directed design, and role-play. Each session was recorded and later analyzed

The first session allowed us to get a better understanding of two main aspects:

- The fundamental role of the previous knowledge that children had on the language of cartoons and videogames as effective mediators of interaction metaphors.
- The definition of the logic behind the behavior of the game during the first session of the game.

The second session allowed us to find more intuitive ways to design the interaction. The use of role-play allowed us to define certain behaviors of the character and its expected reaction to the input of children. Children showed especially strong preference for highly expressive reactions in character behavior. Another important observed aspect was that one child felt uncomfortable seeing his own image represented on the screen. This finding suggested the possibility of adding a customization parameter to the application that would allow changing the visual representation of the player; e.g. from a fully detailed camera image to a plain simple silhouette.

The third session allowed us to evaluate the enjoyability of different game mechanics for the second level. Unfortunately two children were unable to attend this third session and one child spent half the session going out of the room to see his father.

During the fourth session several creative solutions were proposed for the design of the aliens planet. We conducted a directed design activity that proved highly effective in stimulating children collaboration. Several design ideas were proposed and children were highly motivated in specifying their ideas to allow the researchers understand them to draw them properly.

Finally in the fifth session we used the technique of the recalling storyboard (children were asked to draw the story of the game in a storyboard format), which showed particularly effective in terms of its capability to quickly figure out, according to the children, which are the most relevant aspects of the game and therefore focus our design choices.

4.3.2 Final Design

As presented in Section 4.3, the final game was based on an underlying narrative structure inspired in the model of the Heros Journey. Within that the player acted as the Hero who receives a call to adventure and undertakes a journey of challenges toward the objective of promoting social initiation skills. The adventure is guided through the story of Pico, a friendly alien that arrives to the Earth by mistake, due to a weather problem while he is traveling to visit its favorite cousin. Pico lands in the woods and its spaceship breaks down. At the beginning of the adventure, Pico is a little bit scared of being in an unknown world and by the novelty of the environment. The child has to show Pico that he can be its friend. This is accomplished by helping Pico in some tasks such as providing it with food or help it fixing its spaceship. To reward the players for their cooperation, Pico will give them different super-power gifts that will serve as tools to fulfill certain tasks. Also, as a sign of gratitude Pico will invite the players to travel together to its planet. There, after solving certain missions, Pico will finally meet its favorite cousin.

First session

In this session the child gets to meet Pico, the main character of the story. Children can customize Pico in a number of ways to achieve a better empathy and adherence to the character. In order to change the appearance of Pico, the child must select one of the food items that appear in the tree tops of the forest where the action is set. Children must raise their hand

Figure 4.1: In the image we can see a child playing with Pico's Adventure. In this case the child is grabbing the red chilly as requested by Pico.

and reach out for the the target food and keep the hand in that position for a couple of seconds until the food falls to the floor. At this point, Pico will see the food and move toward it, eat it and a magical change will be seen in its body.

The session is divided in four parts, each one changing a different aspect of Picos body: (1) skin colour, (2) outfit, (3) hat and (4) complexion. After each part a set of images appear (as if they were old Polaroid photographs). The child must then select his favorite choice by raising his hand in front of the picture. This will fix that part of customization of Picos appearance for the rest of the game. The selection of Picos final appearance through images has been added in the final version of the game to foster children to do more stimuli discrimination gestures during the session.

In the third and fourth parts of the session, a bird will appear every time the child makes a food item fall to the floor. The bird will stand on the food as if trying to capture it for itself. This impedes Pico to walk to the food item and eat it. The child must then scare the bird away by waving his arms in front of it. Once the bird flies away, Pico will be able to reach the food item and eat it, so the journey can progress.

Second session

In this session the child helps Pico fix its spaceship and fuel it to be able to fly back to its home planet. The game is structured in two main parts. In the first part the child must find the pieces of the spaceship and collect them by raising his hand to reach for them and keeping the hand in this position for a couple of seconds. The pieces fall to the floor and then Pico takes them and mounts them on the spaceship structure. This happens by night, so children need to light the environment to find the pieces. Pico helps children by giving them the superpower of casting light from their hand. This approach was based on the peephole design strategy defined by Dalsgaard and Dindler (Dalsgaard and Dindler 2014). This strategy suggest the use of objects that reveal just small parts of the environment to the users, for fostering exploration.

Moreover, some pieces are too high for the child to reach, therefore he must ask for help to the adult (any relative adult in the room). When the adult enters the play area s/he also appears in the game environment on the screen. The adult must have a passive attitude towards the game and must always wait for the child to provide instructions on which pieces the adult has to reach for.

Once the spaceship is fully reconstructed, the second part of this session starts. In this second part, the child must coordinate with the adult to catch falling stars needed to fuel the spaceship. To perform the action of catching the stars, the child must hold hands with the adult and make the stars fall between their arms. There are yellow stars which are good for the ship and red stars which are not good for it. Hence, the child has to discriminate between the stars that are useful for fueling the spaceship (yellow stars) and stars that are not useful for it (red stars). Pico will celebrate with a cheerful dance or rejection whenever a yellow or red star

Figure 4.2: In the image we can see a child playing with his mother while capturing an energy star for Pico's spaceship.

is collected respectively. When enough yellow stars are collected, Pico, the adult and the children will get inside the spaceship as a cliffhanger.

Third session

In this session the child and the adult travel to Picos planet. The goal of this session is to liberate spaceships that belong to Picos friends which are trapped in some strange evil clouds. In order to perform this action the child and the adult must collaborate. The child and the adult must point together to the spaceship using a laser that each one has in their right hand. The laser is again a tool given by Pico to users. The laser must be directed such that it remains on the cloud surrounding the spaceship until this cloud disappears. The child must give instructions to the adult on where to point and how. Furthermore, they need to match the color of the laser with the color of the cloud.

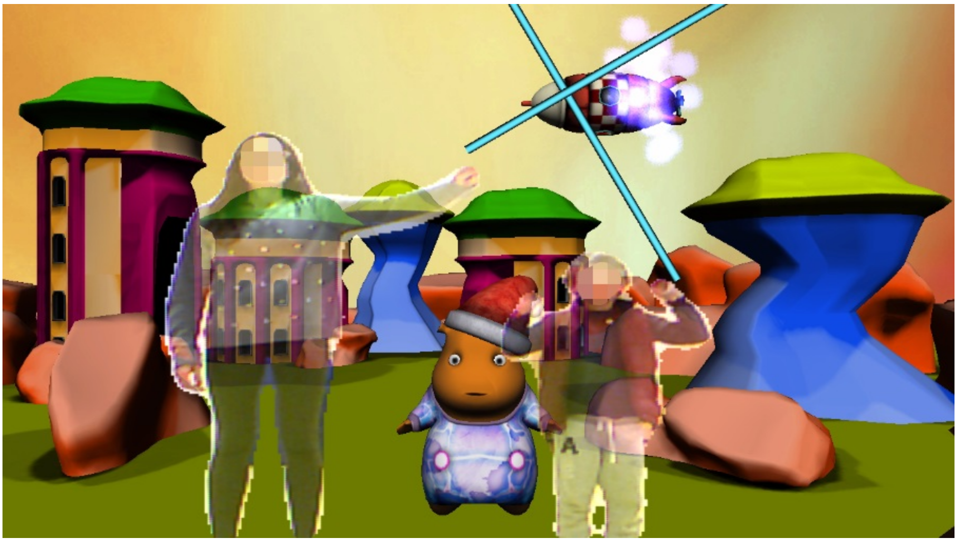

Figure 4.3: In the image we can see a child playing with his mother. Both are pointing with their magic laser to free a trapped spaceship.

Fourth session

In this session two ASD children play together. The goal of the session is to get some presents that the inhabitants of Picos planet offer to them. These presents are to thank the children for having liberated the spaceships from the evil clouds in the previous session. The two children will again use a laser that appears on their right hands. They have to collaborate together by pointing their lasers toward the present boxes that appear in the buildings of Picos planet. When the game starts, the customized Picos of each child appear on either side of the game environment and meet in the center. After the children say hello to them with their hand, the two Picos climb on a flying platform that is parked in the center of the game area. If the two children jointly point at a present with their lasers, they correctly signal the flying platform to fly towards the present. Once the flying platform reaches the present, both Picos take it on board and fly back to where the children are. At this point the two children must touch the present with their hand at the same time to open it. The present in the box then appears and a copy is given to each child.

Figure 4.4: Two children, who never met before, playing together and collaborating to help their Picos collect the rewards during the last session.

We would like to clarify that we had to re-design the fourth session completely from the initial design we did. The changes were lead by the results of the PD conducted in the UETD (described in Section 4.3.1). During the participatory design sessions, the acceptance of the initial proposed design was really low, thus rendering the design not acceptable. It was then decided to reuse existing mechanics to test their adoption and learning by ASD children during sessions. Although the changes on game mechanics and session content, main therapeutic goals remained the same.

4.4 Evaluation

The experimental study aimed at evaluating the effectiveness of the game in eliciting behaviors associated related to social initiation. Such evaluation was accomplished by comparing the amount of targeted behaviors elicited by the game with a baseline evaluation performed through a free play activity. Furthermore the study also evaluated the relation between specific game mechanics and the kind of elicited behaviors.

Formally, the goal of the experimental study was:

- Evaluating the effectiveness of the game for eliciting behaviors associated to social initiation. This was carried out using quantitative systematic video coding to quantify the number of occurrence of targeted behaviors. Furthermore, baseline evaluation of targeted behaviors was performed through the comparison between behaviors elicited in the game and behaviors elicited in sessions of free play with a set of toys.

4.4.1 Hypotheses

Given the objectives of the experimental study, the hypothesis was:

The full-body interaction system will foster more social related behaviors than the free play sessions with a set of toys.

4.4.2 Experimental Design

Since one of the goals of the study was to compare behaviors in the game with a baseline measurement of behavioral tendency of the child, a free play activity with toys was included in each session.

The free play activity was designed to correspond to the situation presented by each play session (Table 4.5). Furthermore, free play and game were alternated according to a counterbalanced measure design in order to avoid biases related to the timing procedure. Children were randomly assigned to two conditions in each session:

a) Condition AB: Free play with toys - Play with the game Pico's Adventure

First children played autonomously for 10 minutes with a set of toys that were placed on the floor. After children played for approximately 30 minutes.

Session	Conditions Free Play	Conditions Game
1	The child plays alone with toys	The child plays in single-user mode
2	The child plays with toys together with the adult	The child starts playing alone but at some point requires help from someone else; e.g. an adult such as a parent
3		The child plays with an adult from the beginning of the session
4	The two children, who have never met before, play together with toys	The child plays the full session together with another ASD child from the experimental group, who have never before met.

Table 4.5: Experimental conditions: "Free Play" and "Pico's Adventure" Game

b) Condition BA: Play with the game Pico's Adventure - Free play with toys

First, children had approximately 30 minutes to play with the game. When they finished the game, children were invited to play with a set of toys (free play) for 10 minutes.

4.4.3 Participants

The participant children were selected according to the following inclusion and exclusion criteria.

Inclusion criteria

Participants were selected through inclusion criteria based on:

- Age range between 4 and 7 years old
- Diagnostic for Autism Spectrum Disorder according to ADOS (Lord et al. 2000) and ADI-R (Lord et al. 1994), applying DSM-IV-TR's criteria
- Cognitive capacity above 70 as measured by the WISC

Exclusion criteria

Participants were excluded in case of meeting one of the following criteria:

- Diagnostic for neurological disorder that could interfere with the interaction with technology (e.g. epilepsy)
- Severe behavioral problems that could incapacitate the subject to participate in the study
- Medication alteration during the time span of the study

Subjects were recruited by the psychologists of the UETD, who contacted parents with children already diagnosed by the UETD and families from the association for parents of children with ASD Aprenem. Parents and children were given initial information about the study. Per the Hospital Sant Joan de Déu review boards, written informed consent was completed by parents.

Diagnosis of ASD was confirmed by the administration of the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994) and the Autism Diagnostic Observation Schedule, Module 2 or 3 (ADOS; Lord et al. 2000). All participants met cut off scores for social interaction, communication and restricted and repetitive behaviors on the ADI-R. According to results from the ADOS, they all had significant social communication difficulties and at least one sign of repetitive behavior.

In order to estimate IQ, the Wechsler Intelligence Scale for Children-IV (Wechsler 1949) was administered to children above 6 years old. Younger participants were administered the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Luiselli et al. 2013) or the Kaufman Assessment Battery for Children (Loomis et al. 2010). Evidence of known neurological disorder that could interfere with the interaction with technology (e.g. epilepsy), severe behavioral problems and/or estimates of full scale IQ ¡70 were exclusionary.

4.4.4 Methods

Data gathering

Observational instrument for quantitative video coding to quantify target behavior during the game were used for measuring desired behaviors.

In the Appendix table (A.2) each of the video coding scheme items used for codifying the session recordings is categorized and described.

The designed observational instrument was used for quantitative behavioral observation of the child while playing with the game Pico's Adventure as well as in the free play activity with toys. Two psychologists and two researchers, trained for observation of child behavior, performed the video analysis.

Data operationalization

The analysis was performed on 5 minutes video slots using Lince, a program for systematic video observation. Time slots were selected according to a pre-established timing based on the appearance of different mechanics in the game. Formally 6 video slots for each child were selected for the game and three video slots for each child were selected for the free play activity (Table 4.6).

To evaluate the reliability between the four coders an initial training was performed until reaching a good inter-rater reliability (¿ 0.8) calculated through the Intra-class Correlation Coefficient (ICC).

Session	Game Video Slots	Free Play Video Slots
1	two video slots (5 minutes each)	one video slot (5 minutes)
2	two video slots (5 minutes each)	one video slot (5 minutes)
3	one video slot (5 minutes)	
4	one video slot (5 minutes)	one video slot (5 minutes)

Table 4.6: Video slots selected for the Analysis of Pico's Adventure

Session guidelines

The session guidelines diverged depending whether children were assigned to Condition A or Condition B:

a) Condition AB: Free play with toys - Play with the game Picos Adventure

After entering in the room the child was invited to autonomously play for 10 minutes with a set of toys that were placed on the floor. After the established time the psychologist introduced the child to the game through a pre-scripted explanation of the basic facts, tasks and challenges they would find in that session. After that, children had approximately 30 minutes to play with the game. After finishing the game children were asked to rate their likeness of the game.

b) Condition BA: Play with the game Pico's Adventure - Free play with toys

After entering in the room the child were introduced to the game by the psychologist. The psychologist told them a pre-scripted explanation of the basic facts, tasks and challenges they would find in that session. After that, children had approximately 30 minutes to play with the game. After finishing the game children were asked to rate their likeness of the game.

When they finished the game, the set of toys were placed on the floor and the children were invited to play with them for 10 minutes.

4.4.5 Procedure

The evaluation of Pico's Adventure was carried out at the Hospital Sant Joan de Déu (Barcelona). During each session children were accompanied by parents and the session took place in a large dedicated room of the hospital where a psychologist and a researcher were present. The parents, the therapist and the researcher were seated on one side of the room while the child was asked to play with the game in front of a table holding a 32 TV screen and a Microsoft Kinect device. The experimental room had an adjacent room from which a second researcher and a second psychologist observed the child through a one-way mirror.

The study was carried out during two months. Each month was structured according to the same schedule. Children were randomly divided into two groups: the first group of 10 children participating during the first month and the second group of 10 children participating during the second month.

A total of 15 boys with ASD were involved in the study (age: M = 5,69; SD = 0,988; IQ : M = 94,40; SD =17,79). The subjects were recruited by the psychologists of the UETD. For the recruitment the psychologists contacted, on one hand, with children already diagnosed by the UETD and, on the other hand, with the association Aprenem for parents of children with ASD. Children were filtered according to the inclusion and exclusion criteria (Section 4.4.3).

As we said, the recruited children were randomly divided into two groups: the first group (initially 10 children, finally 7 children) participated in the experiment in May 2014; the second group (initially 10 children, finally 8 children) participated in June.

During each month, each child participated in a total of 4 sessions, scheduled on a weekly basis. In each session children were accompanied by a parent or an adult relative. As defined by the study, the child played alone in the first session, with one of his parents in the second and third sessions, and finally, played with another child, also included in the treatment, in the fourth session. Each session lasted for one hour in which two main activities were carried out: free play with toys and playing with the Pico's Adventure game.

The free play sessions were recorded with a hidden camera focusing on the play area. The game sessions were recorded with a program that captures the images displayed in the visual output system (Television). In that case, the image not only contained the virtual elements and characters of the game, but also the image of the users as if they were part of the virtual environment. This was achieved thanks to the Microsoft Kinect sensor system that records the child in the physical environment. The system is capable of isolating childs image from the physical background and place the image within the virtual environment. With this system, the video obtained from the sequence of screen capture could show all activity in the game, the corresponding behaviors and responses of the child, as well as his expressions and vocalizations.

4.5 Results

To evaluate the effectiveness of the game Pico's Adventure for eliciting behaviors associated to social initiation we compared the number of target behaviors elicited during the game sessions with the number of target behaviors elicited during the free play sessions according to the procedure described in Section 4.4.4. For this purpose the behaviors related to social initiation described in A.2 were considered.

For each child four different raters coded a total of 6 videos of Pico's Adventure and three videos of free play. To evaluate the reliability between the four coders an initial training was performed until reaching a good interrater reliability calculated through the Intraclass Correlation Coefficient (ICC) as explained in Section 4.4.4. The four raters therefore individually coded the same video and Intraclass Correlation Coefficient (ICC) was

Pairs	Pico's Adventure Session	Free Play Session	Play Condition
1	Video Session 1, Part 1	Video Session 1	Playing alone
2	Video Session 1, Part 2	Video Session 1	Playing alone
3	Video Session 2, Part 1	Video Session 2	Playing with a parent
4	Video Session 2, Part 2	Video Session 2	Playing with a parent
5	Video Session 3	Video Session 2	Playing with a parent
6	Video Session 4	Video Session 4	Playing with another ASD children included in the treatment plan

Table 4.7: Video pairing for comparison

calculated between the coders. This process was iterated until a good inter-rater reliability was reached between all coders for six videos (average ICC =0. 925; p ¡ 0.001). After this first stage each coder proceeded separately to code an assigned subset of the videos. Once an ICC¿ 0.8 was reached between the different coders, each coder proceeded to the evaluation separately.

Each video had a duration of 5 minutes. For each child, Pico's Adventure and free play videos were paired according to equivalent condition of play, as described in Table 4.7 (i.e. playing alone, playing with parents, playing with another ASD child).

The analysis was structured according to two main steps:

- Comparison of overall Social Initiation behaviors by considering the four categories together (Integrated request + Non Integrated request + Integrated Social Commentary + Non integrated social Commentary)

- Comparison of specific Social Initiations occurrence by considering each category as separated.

4.5.1 Comparison of overall Social Initiation

In order to evaluate the overall Social Initiation we used the sum of the quantity of behaviors related to: Integrated request, Non Integrated request, Integrated Social Commentary and Non-integrated social Commentary. Firstly a repeated measure ANOVA was carried out in order to evaluate whether significant differences were present between the different sessions and condition. Mauchly's test indicated that sphericity can be assumed, so no data correction was necessary; $X(35) = 52.43$; $p = 0.085$.

Results indicated that sessions significantly differ between them ($F(8) = 2.85$; $p = 0.00$); thus relevant pair wise comparisons were performed. Specifically paired sample t-tests were conducted to compare the number of occurrence of target behaviors in Picos Adventure condition and in free play condition for each pairs.

In pair 2 (child playing alone) a significant difference was reported in overall social initiation between Pico's Adventure ($M = 9.33$, $SD = 9.61$) and free play ($M = 4.08$, $SD = 3.82$); $t(11) = 2.438$, $p = 0.033$. Furthermore Cohen's effect size value ($d = 0.704$) suggested a moderate to high practical significance.

Also in pair 6 (two ASD children playing together) a significant difference was reported in overall social initiation between Pico's Adventure ($M = 10.93$, $SD = 5.54$) and free play ($M = 6.50$, $SD = 5.11$); $t(13) = 3.60$, $p = 0.003$. Furthermore Cohen's effect size value ($d = 0.962$) suggested a high practical significance. Instead no significant differences were reported for the other pairs (for a summary see Table 4.8 and Figure 4.5).

A linear regression was carried out to evaluate whether differences in the diagnostic could be considered as predictors of children behaviors in the different sessions. Specifically in the regression data proceeding from the different dimensions of the used diagnostic instruments (ADI-R, ADOS)

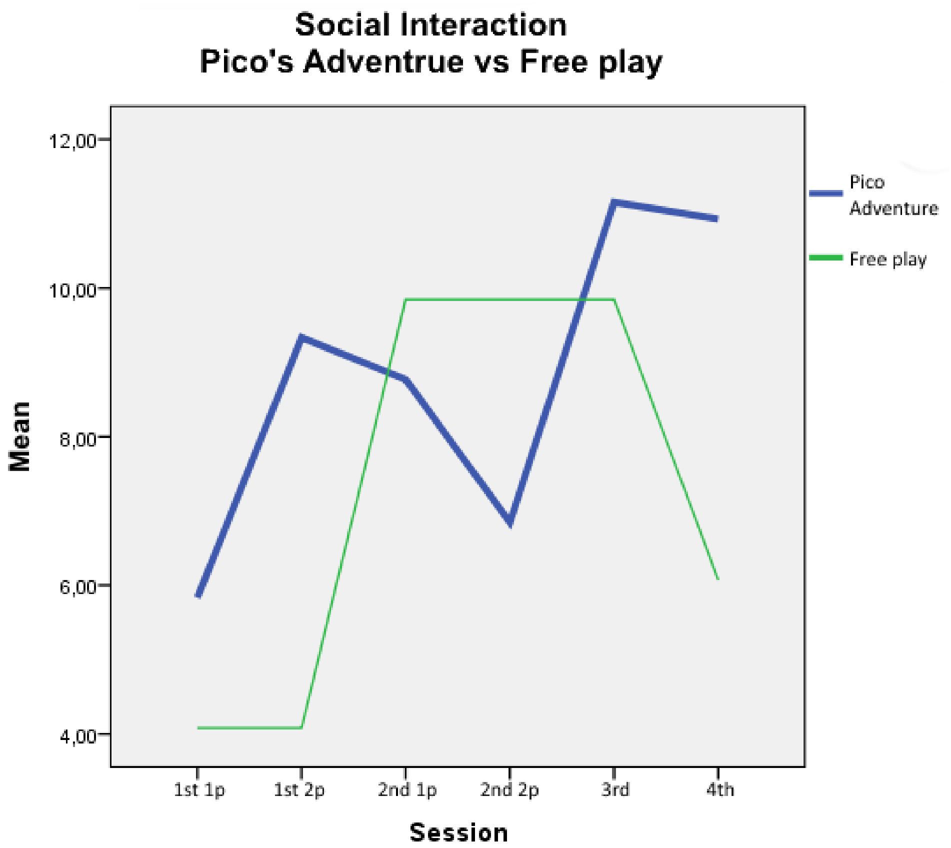

Figure 4.5: Comparing social initiation in Pico's Adventure and free play

were considered in relation with the amount of social initiation during the different sessions. However no significance difference was found suggesting that none of the dimensions of the diagnostic could be considered as a predictor of the amount of social initiation.

4.5.2 Comparison of Specific Social Initiations

In order to provide a deeper understanding of the previously reported results, we performed a detailed analysis considering each category as separated (Integrated Request, Non Integrated Request, Integrated Social Commentary, Non integrated social Commentary). Results proceeding from the

Pairs	Pico's Adventure	Free Play	Comparison	Play Condition
1	Session 1, Part 1 (M = 5.83 ; SD = 6.279)	Session 1 (M = 4.08; SD = 3.825)	t (11) = 1.232; p = 0.244 ; Cohens d = 0.355	Playing alone
2	**Session 1, Part 2 (M = 9.33; SD = 9.614)**	**Session 1 (M = 4.08; SD = 3.825)**	**t (11) = 2.438; p = 0.033; Cohens d = 0.704**	**Playing alone**
3	Session 2, Part 1 (M = 8.77; SD = 5.540)	Session 2 (M = 9.69; SD = 4.837)	t (12) = -0.468; p = 0.648; Cohens d = -0.13	Playing with a parent
4	Session 2, Part 2 (M= 6.85; SD= 6.866)	Session 2 (M= 9.69; SD = 4.837)	t (12) = -1.271; p= 0.228; Cohens d = -0.352	Playing with a parent
5	Session 3 (M= 11.15; SD = 7.403)	Session 2 (M= 9.69; SD = 4.837)	t (12) = 0.881; p= 0.398; Cohens d = 0.244	Playing with a parent
6	**Session 4 (M= 10.93; SD= 5.540)**	**Session 4 (M = 6.50; SD = 5.110)**	**t (13) = 3.60; p= 0.003; Cohens = 0.962**	**Playing with another ASD children included in the treatment plan**

Table 4.8: Summary Overall Social Initiation: Picos Adventure vs. free play

specifics categories are reported in the following sections.

Requests

Paired sample t-tests were conducted for each pairs (Table 4.9) to compare the number of occurrence of behaviors related to integrated requests, understood as social initiation with eye contact with the interlocutor aimed at requesting something to the other, such as asking the other to perform an action or asking for help or information.

A statistically significant difference was reported only in pair 3, where children showed an higher amount of integrated requests in Pico's Adventure (M = 2.331, SD = 2.097) than in free play (M = 0.46 , SD = 0.519); $t(11) = 2.839$, $p = 0.014$. Furthermore Cohen's effect size value ($d = 0.80$) suggested a high practical significance. In this context it is relevant to notice that pair 3 includes the first part of the second level of the game Pico's Adventure (see Table 4.7). In this game's part the child starts playing alone and then is faced with a situation that requires him to ask for help to parents since he cannot reach some of the pieces of the spaceship. It is therefore possible that this situation could have facilitated the elicitation of integrated requests behaviors. Instead no significant differences were reported for the other pairs (for a summary see Table 4.9).

On the other side the comparison of non-integrated requests showed significant difference between pair 2, 5 and 6, in favor of the game Pico's Adventure. At the same time, despite not being significant, also pairs 1, 3 and 4 show a tendency of the game Pico's Adventure toward promoting more non-integrated requests that free play (for a summary see table 4.10).

Social Commentaries

Paired sample t-tests were conducted for each pairs (Table 4.7) to compare the number of occurrence of behaviors related to integrated social commentary, with the interlocutor aimed at drawing the attention to something or sharing experience or making a social commentary. No significant differ-

Pairs	Pico's Adventure	Free Play	Comparison	Play Condition
1	Session 1, Part 1 (M = 0.50 ; SD = 1.243)	Session 1 (M = 0.83; SD = 1.467)	t (11) = -0.650; p = .529; Cohen's d = -0.187	Playing alone
2	Session 1, Part 2 (M = 2; SD = 3.275)	Session 1 (M = 0.83; SD = 1.467)	t (11) = 1.432; p = 0.180; Cohen's d = 0.412	Playing alone
3	**Session 2, Part 1 (M = 2.31; SD = 2.097)**	**Session 2 (M = 0.46; SD = 0.519)**	**t (12) = 2.889; p = 0.014; Cohen's d = 0.80**	**Playing with a parent**
4	Session 2, Part 2 (M = 0.77; SD = 1.097)	Session 2 (M = 0.46; SD = 0.519)	t (12) = 0.938; p = 0.367; Cohen's d =	Playing with a parent
5	Session 3 (M = 0.85; SD = 0.987)	Session 2 (M = 0.46; SD = 0.519)	t (12) = 1.237; p = 0.240; Cohen's d =	Playing with a parent
6	Session 4 (M = 0.86; SD = 1.512)	Session 4 (M = 0.64; SD = 1.151)	t (13) = 0.378; p = 0.711; Cohen's d =	Playing with another ASD children included in the treatment plan

Table 4.9: Integrated requests

Pairs	Pico's Adventure	Free Play	Comparison	Play Condition
1	Session 1, Part 1 (M = 1.25 ; SD = 1.960)	Session 1 (M = 0.17; SD = 0.389)	t (11) = 2.182; p = 0.053; Cohen's d = 0.629	Playing alone
2	**Session 1, Part 2 (M = 1.50; SD = 1.679)**	**Session 1 (M = 0.17; SD = 0.389)**	**t (11) = 3.370; p = 0.006; Cohen's d = 0.973**	**Playing alone**
3	Session 2, Part 1 (M = 2.08; SD = 2.100)	Session 2 (M = 1.69; SD = 3.838)	t (12) = 0.315; p = 0.758; Cohen's d = 0.08	Playing with a parent
4	Session 2, Part 2 (M = 0.23; SD = 0.599)	Session 2 (M = 1.69; SD = 3.838)	t (12) = -1.484; p = 0.163; Cohen's d = -0.411	Playing with a parent
5	**Session 3 (M = 3.62; SD = 4.646)**	**Session 2 (M = 1.69; SD = 3.838)**	**t (12) = 2.260; p = 0.043; Cohen's d = 0.626**	**Playing with a parent**
6	**Session 4 (M = 2.86; SD = 2.905)**	**Session 4 (M = 1; SD = 2.148)**	**t (13) = 2.484; p = 0.027; Cohen's d = 0.664**	**Playing with another ASD children included in the treatment plan**

Table 4.10: Non-Integrated requests

ence was found between any pairs (Table 4.11). However it is relevant to notice that two different tendencies are present. Pico's Adventure tended to favor a higher number of social commentaries than free play in pair 1, 2 and 6, when the child is either playing alone (pair 1 and 2) or with another child (pair 6). Instead free play tends to favor more social when the child is playing with his parents (pair 3, 4 and 5).

Such tendencies are confirmed by the analysis of non-integrated social commentary (Table 4.12). In this case significant difference between pair 3, in favor of the free play activity; t (12) = -2.202, p = 0.048.

A possible explanation of these results could be related to the level of parent intervention. Despite parents were instructed to remain passive and wait for children initiations, this instruction was not always completely respected. To address this issue four raters evaluate the level of parent intervention using a 1 to 5 scale. A Wilcoxon Signed-ranks test was performed to compare the level of parents intervention in free play and Pico's Adventure. Results indicate that parents intervention was higher in free play (Mdn = 3) than in Pico's Adventure (Mdn = 2) during the second session (pair 3 and 2), Z = 2.01, p = 0.044. Instead no difference was reported for the third session (pair 5), Z = 0.67, p = 0.5. Nonetheless, no significant correlation was found between the level of parents' intervention and the amount of children social initiation, suggesting that this variable may not have played a major role.

4.6 Conclusions & Discussion

Results from the experimental study show that the game Pico's Adventure could be considered more effective than free play in promoting social initiation in ASD children when they are playing alone or playing with a peer. Moreover, it was as effective as free play in promoting social initiation while playing with parents.

A possible explanation of these results can be related to the fact that, when playing alone or with another child, the child is not provided with the

Pairs	Pico's Adventure	Free Play	Comparison	Play Condition
1	Session 1, Part 1 (M = 2.33; SD = 4.119)	Session 1 (M = 1.17; SD = 2.552)	t (11) = 0.848; p = 0.414; Cohen's d = 0.245	Playing alone
2	Session 1, Part 2 (M = 2.75; SD = 3.911)	Session 1 (M = 1.17; SD = 2.552)	t (11) = 1.511; p = 0.159; Cohen's d = 0.436	Playing alone
3	Session 2, Part 1 (M = 1.77; SD = 2.048)	Session 2 (M = 3.08; SD = 3.303)	t (12) = -1.367; p = 0.197; Cohen's d = -0.379	Playing with a parent
4	Session 2, Part 2 (M = 2.77; SD= 4.549)	Session 2 (M = 3.08; SD = 3.303)	t (12) = -0.235; p = 0.818; Cohen's d = -0.065	Playing with a parent
5	Session 3 (M = 2.31; SD = 2.016)	Session 2 (M = 3.08; SD = 3.303)	t (12) = -0.823; p = 0.427; Cohen's d = -0.212	Playing with a parent
6	Session 4 (M = 3.36; SD = 3.191)	Session 4 (M = 1.36; SD = 1.447)	t (13) = 1.898; p = 0.080; Cohen's d = 0.507	Playing with another ASD children included in the treatment plan

Table 4.11: Integrated social commentaries

Pairs	Pico's Adventure	Free Play	Comparison	Play Condition
1	Session 1, Part 1 (M = 1.75 ; SD = 2.701)	Session 1 (M = 1; SD = 1.595)	t (11) = 0.813; p = 0.443	Playing alone
2	Session 1, Part 2 (M = 3.08; SD = 3.118)	Session 1 (M = 1; SD = 1.595)	t (11) = 1.936; p = 0.079	Playing alone
3	**Session 2, Part 1 (M = 2.62; SD = 2.663)**	**Session 2 (M = 4.46; SD = 2.787)**	**t (12) = -2.202; p = 0.048**	**Playing with a parent**
4	Session 2, Part 2 (M = 3.08; SD = 4.387)	Session 2 (M = 4.46; SD = 2.787)	t (12) = -0.990; p = 0.342	Playing with a parent
5	Session 3 (M = 4.69; SD = 3.351)	Session 2 (M = 4.46; SD = 2.787)	t (12) = 0.177; p = 0.863	Playing with a parent
6	Session 4 (M = 3.86; SD = 3.231)	Session 4 (M = 3.50; SD = 3.716)	t (13) = 0.340; p = 0.740	Playing with another ASD children included in the treatment plan

Table 4.12: Non-integrated social commentaries

structure and familiarity that is offered by parents. Such results suggest that Pico's Adventure could be considered as an effective tool to facilitate conditions for social interaction with unfamiliar people. This aspect is extremely relevant in autism since, as we have seen in 2.1.1, major difficulties are present in having to communicate and starting a social interaction with an unknown person (Kasari et al. 2008). At the same time, such finding suggests relevant guidelines on the possible context of use of the game. While in our initial design the game was mainly oriented toward a domestic usage, current findings suggests that greatest benefits could be achieved by its usage in social environments such as schools, special education centers, day care centers and play dates.

The deeper analysis of the kinds of social initiations suggests the efficacy of the game in promoting social requests (e.g. asking for help. giving instructions). As reported in Tables 4.9 and 4.10, Pico's Adventure reports a significant higher amount of social requests than free play in almost all the analyzed pairwise comparisons. Spontaneous requests in children with autism represents a life-long learning skill since it facilitates social interaction and improves quality of life. From this perspective, the game can be considered as an effective instrument to promote and train these target behaviors in a playful and engaging way.

On the other side results related to social commentaries (Tables 4.11 and 4.12) show that the game was not more effective than free play in eliciting children spontaneous expressions such as sharing their emotion and experience. Such shortcoming requires a further research on adequate games stimuli capable of promoting a higher willingness of producing spontaneous commentaries in children.

In order to properly evaluate the effectiveness of specific designs and to inform the development of future works we performed a detailed analysis to evaluate the effectiveness of the different game mechanics (defined in Table 4.13 depending on each sessions activities) in eliciting target behaviors (integrated requests, non integrated requests, integrated social commen-

Mechanic	Description
1.1	The child has to select different food items that appear in the trees to feed Pico. Also understood as an **Initial simple mechanic with discrimination of stimuli**.
1.2	The child has to select different food items that appear in the trees and scare a bird. Also understood as **Discrimination of stimuli with an antagonist**.
2.1	The child has to grab pieces of the spaceship that are scattered on the trees. He needs help from the parents to reach the ones that are too high. The environment view is limited, also understood as the **peephole mechanic**.
2.2	The child has to capture falling stars; he must hold hands with the adult and make the stars fall between their arms while **Holding hands**.
3	The child and the adult should **point together** to the spaceship using a laser that each one has in their right hand to liberate the spaceship from a cloud.
4	The two children have to use the laser and collaborate together by pointing their lasers toward the boxes that appear in the buildings.

Table 4.13: List of game mechanic's specific to game sessions

taries, non integrated social commentaries). A series of paired t-test were performed between the different mechanics. Founded significances are reported in Table 4.14. In the next subsections we will do a more detailed discussion of the different game design and mechanics for Pico's Adventure.

4.6.1 Third-person approach

One relevant research direction should address the analysis of the affordances of the physical interface. As Table 4.10 and Table 4.12 report, mainly non-integrated forms of social initiation were promoted. Such aspect, besides being coherent with autism literature related to the difficulties of ASD people in integrating their initiation with gaze directed to the interlocutor,

Pair	Global	Integrated Request	Non Integrated Request	Non Integrated Social Commentaries
1.1 vs 1.2	1.2 (t(14)= -2,436; p= ,029)			1.2 (t(14)= -2,820 p= ,014)
1.1 vs 2.1		2.1 (t(14)= -3,003; p= ,009		
1.1 vs 3	3 (t(14)= -2,976; p=,010)			3 (t(14)= -2,534 p= ,024)
1.1 vs 4	4 (t(14)= -2,993; p=,010)		4 (t (13)= -2,200; p=,047)	
1.2 vs 2.2			1.2 (t(14)= 3,413; p = ,004)	
1.2 vs 4			4 (t(13)= -2,267; p= ,041)	
2.1 vs 2.2		2.1 (t(14)= 2,238; p= ,042	2.1 (t(14)= 3,336; p=,005)	
2.1 vs 3		2.1 (t(14)= 3,434; p= ,004		
2.1 vs 4		2.1 (t(13)= 2,393; p= ,032		
2.2 vs 3			3 (t(14)= -2,539; p= ,024)	
2.2 vs 4			4 (t(13)= -3,551; p= ,004)	

Table 4.14: Comparison of amount of socializations between scenario's game mechanics

also raise relevant research questions related to the affordances of the used interface. The use of a technical set-up based on the Microsoft Kinect and a television requires players to stand one side the other and both facing at the screen. This approach is understood as a third-person paradigm, where users do not have a 1:1 relation with the virtual environment, but they are represented inside it. Pares and Altimira list the characteristics and differences between the first-person interaction paradigm and third-person paradigm (Parés and Altimira 2013).

Such configuration could have had a series of impacts. First, when using a third-person paradigm, users need to do an initial process of mentally mapping their virtual representation with themselves, for later doing the proper mapping of their actions with the virtual environment. This might suppose an initial cognitive load which might hinder the initial experience of the users with the game. Second, we believe this setting could have been limiting the amount of gaze physically directed toward the other player given that users could at him/her directly at the TV. As users were "present" in the virtual environment, users could look at the avatars faces in the TV. Third, nowadays use of multi-touch devices is ubiquitous. Although all participants finished using properly the system configuration, some children used to get close to the screen during the first session to try interacting with the virtual environment. This posed a problem as Microsoft Kinect has some physical limitations as users must be a minimum of a meter and a half away of it for being tracked.

It would be therefore useful to explore the impact of different spatial configuration and physical affordances on patterns of social interaction.

4.6.2 Simple initial mechanic with discrimination of stimuli

The use of a simple initial mechanic for getting acquainted with the system seemed to be positive. Davis et al. suggest that when developing technology for individuals with ASD, it is recommended to start with simple to grasp mechanics, for later introducing more complex mechanics (Davis et al. 2010). Given that all 15 participants could interact properly with the system, and that we did not have any dropout related to problems with interacting with the system, the approach of designing a first simple scenario for getting acquainted with the system, the game and the virtual agent seemed to be positive.

Nonetheless, as it is possible to see in Table 4.14, the first game mechanic (1.1) favors a lower amount of social initiations with respects to all other mechanics (except 2.2). Such results could be due to an adaptation phase since this first part represents the first fifteen minutes of play and the child might be trying to adapt itself to the interaction paradigm and the system gameplay.

4.6.3 Discrimination of stimuli with and antagonist

After starting with a really simple mechanic that could help children understand their physical relation with the environment, as also getting to know the game and Pico, it was introduced the antagonist. As described in the design of the game, in the third part of the first session a bird suddenly appears, and children need to scare it with their hands to help Pico eat the food.

As we can see in Table 4.14, this mechanic design (referred as 1.2) favored a significantly higher amount of non integrated social commentaries compared to the same mechanic without the bird. Introducing a non-expected element by the children seemed to be successful into promoting new socializations. Thus we encourage adopting the design guidelines of introducing gradually novel elements as Davis et al. suggested (Davis et al. 2010). Furthermore, this goes in consonance with the research of Alcorn et al. (Alcorn et al. 2014) on how novel unexpected feedback can foster childrens initiations.

4.6.4 Peephole and forcing the need to ask for help

At the beginning of the second session children need to explore a dark forest with a magic light. We devised this mechanic to foster childrens exploration, as users would have to actively move their hands around the environment to find the scattered spaceship pieces. Restricting what users can see to reveal just a small part where users interacts is known as a peephole. This is a design strategy which Dalsgaard and Dindler (Dalsgaard and Dindler 2014) have shown to be positive for promoting exploration. In the case of children with ASD, who have difficulties when presented with numerous stimuli, peepholes can also help them focus on a single piece of information and eliminate distractions.

Moreover, to this mechanic it was added that some pieces would not be reachable by the children when playing. Thus, children will need to ask for help not only for finding the pieces, but actually for reaching them. From the results in Table 4.14, we can see that this design combination (with the name 2.1 from Table 4.13) was really successful on significantly increasing the amount of requests done during this part of the game.

From these results we suggest that the use of an enforced need of having to ask for external help for achieving a goal are good design guidelines for promoting social requests in children with ASD.

4.6.5 Holding hands

On the other side it is relevant to notice how game mechanic 2.2, where children has to capture falling stars by holding his hands with the adult, promoted significant fewer social initiations then all other mechanics (see Table 4.14). Such finding could suggest that game mechanics where the child can easily substitute communication with an instrumental use of the other (i.e. pull or push him in the intended direction) could be ineffective to support social initiations.

We therefore suggest that further research in games for autism should address a careful fine-grain analysis of the potential and limits of different design choices. During our design process we envisioned the idea of having the child holding hands with an adult as a good way to ensure socialization through the need of coordination. But we observed that in our game it generated instrumental use. Game mechanics where the child can easily substitute communication with an instrumental use of the other (i.e. pull or push him in the intended direction) could be ineffective to support social initiations.

4.6.6 Pointing to objects and the need to coordinate

In the last two sessions users have a magic power that they can use by pointing towards the virtual elements in the environment. This approach was adopted to help users practice joint-attention abilities. What we can see from results in Table 4.14, is that this mechanic tended to generate more non-integrated requests than most other mechanics. We can conclude that the mechanic was effective for fostering more demands of the children to their peers for achieving a common goal, while also having to physically do the pointing gesture. Nonetheless, with the physical approach adopted, we believe this design might present some shortcomings. First, having to point through a third-person paradigm means that physically the user is not really pointing the virtual element, but that the user has to do the pose for achieving a pointing in the virtual environment. Moreover, this approach seems to require also from the users to be all the time looking at the screen for making sure where they are pointing, thus preventing them from applying integrated socializations.

Chapter 5

Promoting collaboration and social inclusion

Publications

This chapter is based on the following publications:

- Laura Malinverni, Joan Mora-Guiard, Narcis Pares (2016) Towards methods for evaluating and communicating participatory design: A multimodal approach. International Journal of Human-Computer Studies, Volume 94, October 2016. pp. 53-63.
doi: 10.1016/j.ijhcs.2016.03.004

- Joan Mora-Guiard, Ciera Crowell, Narcis Pares, Pamela Heaton (In press) Lands of Fog: Helping Children with Autism in Social Interaction through a Full-Body Interactive Experience. IDC '16: Proceedings of the 2016 conference on Interaction design and children.
doi: 10.1145/2930674.2930695

- Joan Mora-Guiard, Ciera Crowell, Narcis Pares, Pamela Heaton (In press) Sparking social initiation behaviors in children with Autism through Full-body Interaction. Special Issue on International Journal of Child-Computer Interaction in Designing with and for Children with Special Needs.

In this chapter, we will present the last research project we did for exploring full-body interaction technologies for children with ASD. The research project we describe is called “In-Autis-Tic: integració social dels nens amb autisme a travs de les TIC” (Social Integration of Children with Autism through ICT) and was funded by the RecerCaixa 2013 grants program (from February 2014 to January 2016). More precisely, we will be describing the design, development and evaluation of the installation we developed for the In-Autis-Tic research project, the Lands of Fog interactive system. We developed the interactive project within the Full-Body Interaction Lab in the CMTech research group at Universitat Pompeu Fabra in Barcelona (Spain) with the collaboration of lead psychologist Pamela Heaton from Goldsmiths (University of London) and the Special Unit for Developmental Disorders (UETD) from Hospital Sant Joan de Du (Barcelona).

The project was inspired by a full-body interaction artistic installation for the general public called “El Ball del Fanalet” (Lightpools in Catalan) (Hoberman et al. 1999). The artistic project was developed for exploring the social potentials of full-body interaction technologies for developing multi-user experiences. Up to four users explored a virtual environment through the use of hand-held pointers shaped as “fanalets” (paper lanterns in catalan). While exploring, users could “feed” very basic virtual objects, called proto objects, with light to obtain more complex abstract objects, which later could be trained to perform simple choreographies or complex choreographies between different users.

In 2001, a group of children with ASD did an informal play session with Lightpools. This experience showed the potential of the installation to spark social interaction behaviors in HFASD children. Thus, the original artistic approach of fostering social interaction in typical users seemed to be also useful for children with ASD. Years later, we decided to formally explore this potential and take advantage of selected formal properties of Lightpools in a new experience completely conceived for ASD children. Lands of Fog became the resulting experience, using a similar interaction paradigm to Lightpools but applying a contemporary view on autism and allowing children with ASD to collaborate in the creation through participatory design.

5.1 Goals & Requirements

The primary goal of the In-Autis-Tic research project was to design a full-body interactive environment where children with HFASD could learn social interaction behaviors and understand the benefits of collaboration while playing, exploring, and being creative alongside a typically developed companion. We decided not to address specific social skills since we believe that a first essential step in the process of helping children with ASD is to help them in finding mechanisms for social initiation (making demands, joint-attention, non-verbal communication, etc.) and help them realize that, very often, it is better to collaborate with others than to work on their own. Given the affinity that children with ASD show towards ICT technologies, the project aimed to explore the potential of a different full-body interaction media for developing systems for therapy and intervention.

As we have previously seen full-body interactive virtual environments allow for users to physically move in space and within the virtual environment. In the case of collaborative virtual environments, multiple users may be collocated in the experience. Given that users have their peers and content close at hand, full-body interaction media have the potential for developing systems where users can construct deep meaning from the activity as their conscious thought processes are embedded in the context (Jonassen and Rohrer-Murphy 1999).

We set as a goal the promotion of collaboration for three reasons. First, for collaborating it is required different types of communication from the users to agree on their common goals and the strategies to attain them. This makes them naturally practice social communication abilities. Second, promoting collaboration might help users to see their peers as valuable play partners. Given the challenges in social integration and maintaining social relationships in children with ASD, which we described in Section 2.1.1, creating scenarios where users see each other as valuable partners could help in developing and maintaining friendship. Social inclusion has benefits for children with ASD as it helps them acquire and develop positive social skills (Gupta et al. 2014), and helps to generalize their social skills to new contexts (Strain 1983). Finally, placing children with ASD in a collaborative context can be a scenario to teach them that often working alone does not allow to reach their goals, and that they need the help of others to succeed.

Another goal of the project was to develop a system that would intelligently respond to children's behavior and adapt to the different contexts. The system was designed to reduce user's anxiety by gradually introducing new elements, while offering a high aesthetic value that would match available commercial videogames and would therefore meet children's expectations.

5.2 Interaction Design

We present the interaction design strategies for achieving the goals, therefore, the description of the interaction design process will be organized according to these objectives. In this section we are going to describe each design strategy by framing it in relation to the previous experience with Lightpools, our knowledge as interaction designers, the PD workshops described in the next section (Section 5.3) and related technical considerations.

5.2.1 The physical interface

We designed the physical configuration of the experience around a large circular floor projection of 6 meters in diameter. This is based on the experience of Lightpools which also used this configuration for the artistic project. The circular projection does not provide corners in which children with ASD can isolate themselves from the typically developed child, and movement is always directed back into the main playing area, fostering serendipitous encounters between users, thus providing opportunities for them to start interaction; either physically, or through the events occurring in the VE. Additionally, the diameter of 6 meters allows for free roaming of the children within the VE. This approach gives users freedom to easily adopt exploratory attitudes towards the virtual environment as they wander through the physical space. This large physical size allows each user to have their own space and not feel the pressure to interact with the other.

From the experience with Lightpools, we decided that children would have a physical pointer in their hand to interact with the world. The use of a physical pointer was two fold. From a technical perspective, we used the pointer for tracking users in the interactive space. From an interactive point of view, the pointer also worked as a cognitive offloader for the users. We believe the pointer helps children with ASD to focus on the relevant virtual content, which helps them to better grasp the system's responses to their actions. This approach seemed successful in Lightpools to help users focus while interacting with the system. Having a physical object tied to a virtual representation can help users to form the mental mapping between the physical and virtual world. This approach allows us to keep a first-person interaction while adding elements that help users to focus and understand the relation of their actions with the environment.

5.2.2 Design Strategies

We will now proceed with the explanation of the different interaction design approaches taken for the development of the Lands of Fog installation based on engagement, socialization and collaboration:

Engaging the user

As ASD is characterized by limited interests and repetitive behaviors (Section 2.1), we have previously commented that one of the objectives of the project was to design an installation that would engage children with ASD to play. We believe this is a necessary initial step when designing tools for assisting therapy or intervention for individuals with ASD, as it is important to keep users engaged to maximize the desired outcome of the sessions.

A world covered by fog We designed the virtual world in collaboration with the children with ASD during some PD sessions. With the PD participants we designed the virtual world to be a unique place where different kinds of biomes meet and where strange and unique insects and creatures live. The world is based on four different environments that coalesce in a unique space. The virtual world is a place where a grass field with a river lies beside a snowy and icy patch, which meets a solidified magma terrain, all traversed by a cobbled road. Children specified that each zone would be populated by unique objects and creatures. See figure 5.1.

In Lands of Fog the users cannot see all of the VE at once. This is similar to how Lightpools worked. The idea is that if the users were allowed to see the entire VE at once, they would be less motivated to explore the space by physically moving around. Hence, we thought the VE needed to be covered by a layer of fog and the users would only be able to see part of the environment through a hole in the fog. As the system tracks the user's position, it opens a hole in the virtual fog at that point and reveals part of the hidden VE. As the user moves in space, the hole follows him and he can then start to understand the structure of the VE. Having a rich world covered by a layer of fog was meant to motivate users' engagement and exploration by increasing the interest to discover surprising elements which may lie below.

This practice of restricting the view to reveal only a small section of the scenario is referred to as creating a peephole, a design strategy which Dalsgaard and Dindler Dalsgaard and Dindler 2014 have shown to be a good practice for promoting exploration. In the case of children with ASD, who typically have difficulties multitasking when presented with numerous stimuli, peepholes, such as the openings in fog, can also help them to focus on a single piece of relevant information and eliminate distractions, which could be a source of anxiety.

Hunting insects Children with ASD sometimes adopt passive attitudes when placed in unknown environments. Because of this, and also to foster

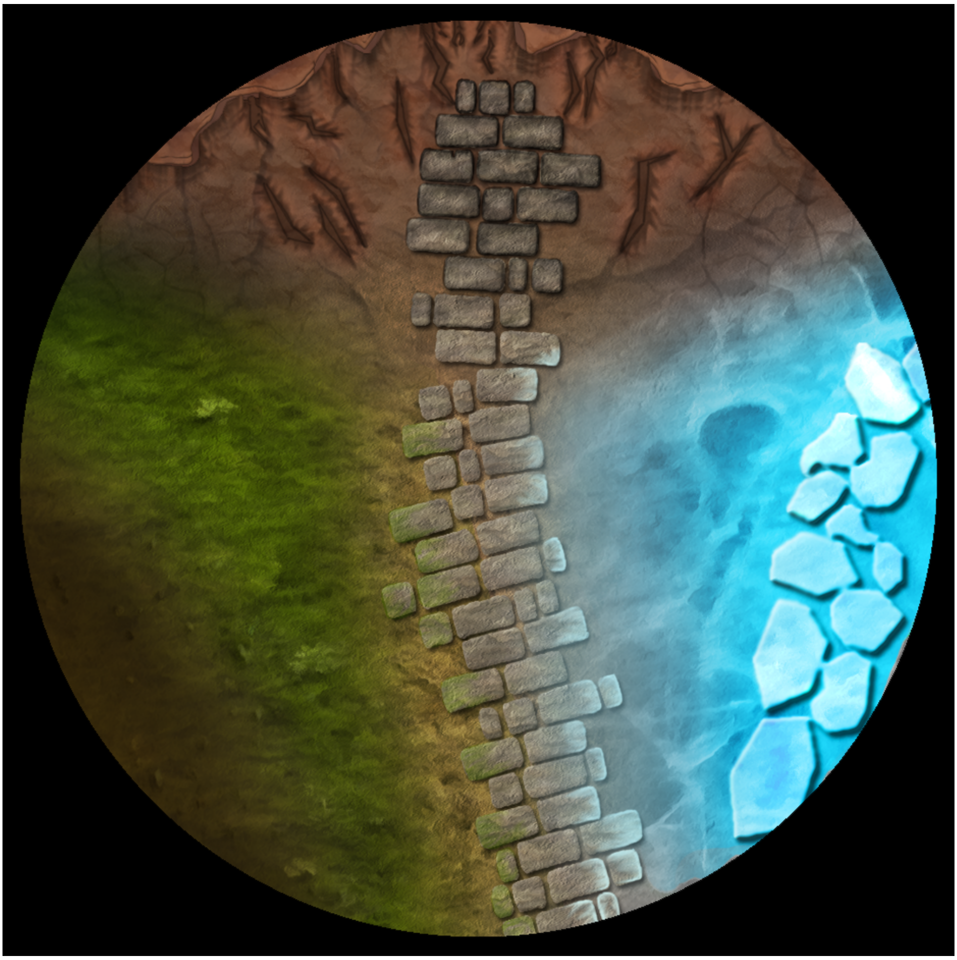

Figure 5.1: Overview of the environment. On top there is the lava zone, to the left the grass and in the right the ice zone. In the middle one can see the cobblestone path.

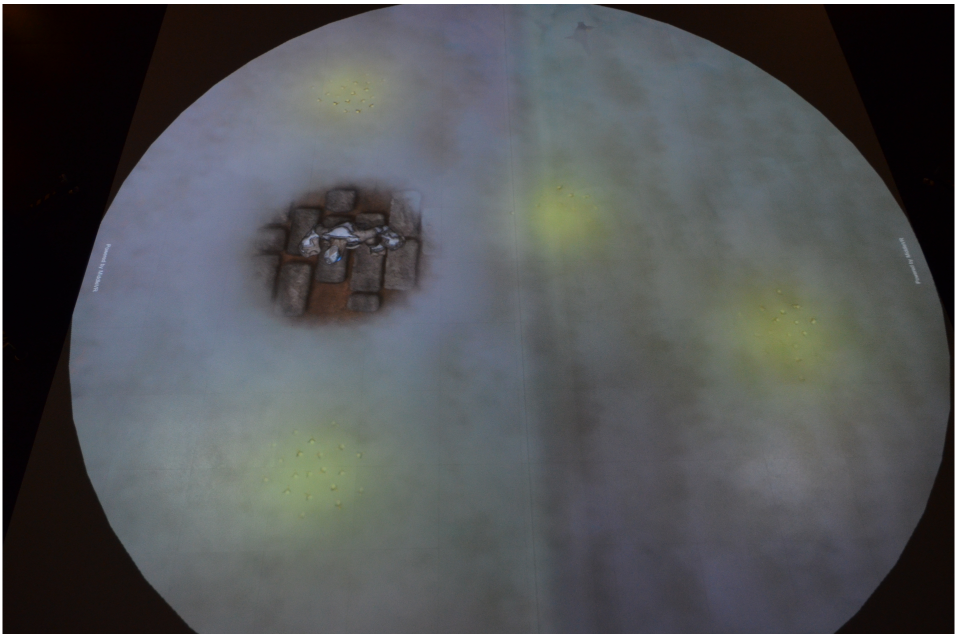

Figure 5.2: The lit circles signify swarms of fireflies moving just below the fog. The user sees the world below through the hole in the dense fog.

exploration of physical and virtual space through the hole in the fog, the users can catch elements which move about in flocks through the virtual fog. These elements appeared in the form of swarms of insects. These swarms move about in random trajectories above and below the fog. The idea is to make children curious about these swarms which appear and disappear. If the child shows no special interest for these swarms during a limited time, the system subtly changes their trajectories gradually bringing them closer and closer to the child so as to make them more evident and more accessible to him, even up to a point in which the child can catch some of the insects in the swarm almost without effort. This subtle reaction of the system is not noticed by the child and therefore an extra help is provided without stigmatizing him. This game mechanic, which was not used in Lightpools, has been introduced in the design specifically considering the requirements for children with ASD.

To attract users' attention, we decided that the insects would emit a bright light, so children could see "pools of light" moving below the fog. See figure 5.2. Nonetheless, these flocks occasionally fly above the fog to show that some virtual objects exist in the virtual environment. During the PD sessions children proposed that the insects could be fireflies, and that these could be captured by hovering the net over a nearby swarm. The captured fireflies would then follow the user as they continued exploration.

In the final design, when users bring their nets close to the flocks of fireflies, two insects are caught. This is represented by changing the fireflies' color to match the user's butterfly net color while the rest of the flock moves away from the user. Making the swarm move away from the user was implemented so if users wanted to continue hunting insects, they would have to move around the environment, promoting spontaneous exploration.

After hunting a certain amount of insects, it was decided that fireflies would transform into a creature that would become a virtual partner for the user. The design strategy of beginning interaction with simple objects and transitioning to more complex objects was adapted from the Lightpools project, where users could grow simple proto-objects into virtual partners. These partners opened a richer interaction level with the system. Adapting this interaction mechanic, in Lands of Fog novel elements were introduced gradually during the experience through the repetition of an easy to grasp mechanic, a design approach suggested by Davis et al. (Davis et al. 2010).

Creatures Lightpools' virtual partners were seen as helpful elements for fostering socialization. When adopting the mechanic of having virtual partners in Lands of Fog, we imagined that creatures could be suitable for subtly driving users together and gently introducing opportunities for collaboration. In Lands of Fog, it was decided creatures would follow the users while they are moving around the environment, as virtual partners did in Lightpools, so the children could form a sense of empathy and companionship with their creature (see figure 5.3).

During two PD sessions children gave ideas regarding the different creatures

Figure 5.3: Two pointers held together with both users' creatures below.

that could inhabit the virtual world. Children proposed creatures such as a Yeti, a Golem, a Coral Girl, and even a Crab Man. There were a total of 14 creatures that could be discovered, and each child could only have one creature at a time. The creatures were associated with the different regions of the environment. The PD participants also had the chance to define how the creatures would appear and interact.

One of the first new interactions that we devised happens when only one user obtains a creature. At this point, the user is able to share the creature with the other user by moving their nets together, constituting an easy interaction and thus simplifying the understanding that things can be shared.

In order to maintain user engagement with the system, as users continue hunting insects their creature changes appearance. This mechanic was implemented to foster the children's sense of exploration as they discover different versions of the creatures. In total, there were 4 different versions for each creature, summing up to 56 creature possibilities.

Interactive virtual elements In Lands of Fog the virtual environment is filled with interactive virtual elements that are hidden by the fog and can only be discovered when users get close. This approach for motivating users to explore is inspired by how users discovered elements in Lightpools by moving their lanterns around the play area. When thinking about the objects that users would interact with, we thought these elements could be transformed. Transforming those elements seemed an interesting way to generate surprise, thus fostering dialogue and social initiation with other users (both in TD children and in children with ASD).

Children with ASD in the PD sessions had the chance to propose what kind of objects could be found in the environment, a total of 16 different objects. Children suggested the reactions of the objects when transformed, and unique animations and sound effects that would catch the interest of the players. Having different virtual elements to transform was meant to engage users to continue exploring for novel features in the environment.

Promoting socialization

The main goal of the research project was to develop a system where children with ASD could learn and practice social skills. As previously mentioned, collocated experiences can maximize the cognitive outcomes of social experiences, thus the game was designed to allow for two players to play together. This situation could also help for the typically developed children to see the children with ASD as valuable play partners, encouraging social integration.

As the system had to account for player navigation, movement of virtual objects, and interaction with virtual elements embedded in the environment, it was necessary to find a way to manage how all these would interact with each other.

Reducing competitive behaviors Rather than using competition as a motivator for engaging in gameplay, we wanted to use positive values to dissuade the children from embracing a competitive mentality. Plot strategies aimed at preventing competition included creating a sense of empathy between the children and their creatures, and teaching the children about the positive effects of collaboration.

While the children were collecting insects, there was a risk that they would try to steal insects from their partner or compete for the same insect swarm. To prevent this, we employed three design strategies. The first strategy involved programming the insects to stay dispersed evenly over the virtual world, so there was no moment in which the swarms clustered together. By preventing insects from grouping together, children would not be tempted to compete for the same group of insects. The second design strategy was to change the insects' body color to the player's pointer color after they had been caught. This helped children to understand that those insects now belonged to their personal swarm and were not available to be caught by the other partner, preventing players from trying to rob insects from the other player. The third strategy was to represent the swarm of collected insects as an uncountable cluster that grew. Not having a clear amount of insects would prevent children from trying to compare their numbers of fireflies.

The game was designed to embrace an open ended play format as in Lightpools, where users could continue playing for an undefined length of time. This was adopted so that children would not be focused on competing to reach a particular goal or ending, but would rather focus on the process of exploring the world with their partner and sharing their discoveries. Therefore we designed the game to lack a concrete plot line or ending.

Scaffolding collaboration

As described previously, when both users had a creature, users would discover new game mechanics when bringing their creatures together which enabled them to play the game collaboratively.

One mechanic was when users brought their creatures together, these would combine and create two new creatures, which replaced the old ones. In the PD sessions children suggested that the merge could be represented by both creatures jumping towards one another and transforming into a novel creature. Therefore if the children wanted to discover all the creatures that inhabit the virtual world, they had to plan and work together to merge their creatures.

Another mechanic was when both children brought their creatures to a virtual element of the game, the creatures would interact with it and produce an animated response from the element. By including these surprising game responses, the children could learn that when playing together, they would be able to experience a more exciting and surprising gameplay than playing alone.

Encouraged collaboration When designing Lands of Fog, we decided to give children the chance to play by themselves so they could have their own unique game experience. We have seen from previous research that children with ASD show a tendency towards solitary play, and we wanted to give them the chance to be comfortable in the environment and choose their preferred style of playing. Once they understood the basic gameplay mechanics, we decided to slowly introduce the concept of playing together with their partner with the use of collaborative mechanics and shared objectives. Nonetheless, we wanted to adopt what we call an "encouraged collaboration" approach, which means that children were not forced to collaborate in the game. Instead, the game presented interesting incentives so the children would want to collaborate by their own volition.

5.3 Design & Development

Once we decided most of the different interaction mechanics we wanted to implement for having a system that would achieve the goals proposed, we first conducted a series of participatory design sessions which would help us finally refine the interaction and content design of Lands of Fog:

5.3.1 Participatory Design

For the design of the Lands of Fog interactive system we adopted a Participatory Design (PD) Ehn 1990 approach. Five PD sessions were conducted with 4 male children with HFASD. As Autism is more prevalent in males than females in a ratio of 5 to 1, it was agreed with the lead psychologist that we would work with male children with ASD in the project. Different approaches were adopted for helping children express their insights and provide content for the final design. The five PD sessions were designed in an incremental fashion. During the first two sessions children had the opportunity to define the aesthetics of the virtual environment of the installation. Each child designed their own environment, and all the ideas were subsequently discussed and integrated into a final environment design. In the following two sessions children were able to propose elements and creatures that would inhabit the world they designed and how these would behave and interact. Finally, in the last session the 4 children with ASD had the chance to embody the potential gameplay of the full-body interaction system in a Wizard-of-Oz activity. This consisted of a system that projected on the floor the designs of the children drawn on paper to allow them to experience their designs at full-body scale. For an in-depth explanation of the PD process conducted for the design of this project refer to Malinverni et al. 2016.

5.3.2 State diagrams for game design

Once we had all the game mechanics and content specified, we started to lay out which would be the desired users' behaviors, and the correspondent behaviors of all the virtual elements to respond to users' actions. For managing this amount of potential states and the relationships between them, we decided to use state diagrams. Thanks to the state diagrams we could model different behaviors that users would adopt, and relate them with system responses. For a visual reference see figure 5.4. Diagrams allowed for representing the logical states of the users and virtual elements while the system was running. System behaviors which responded to users'

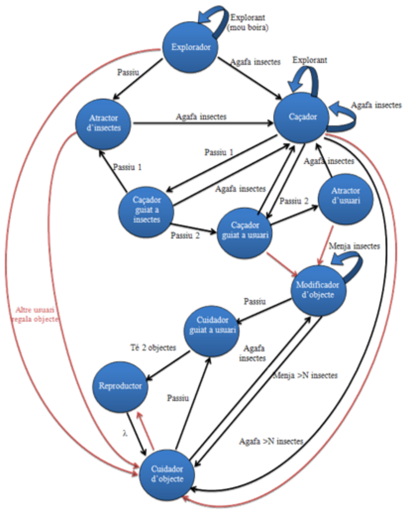

Figure 5.4: Initial State Diagram for a player's logical state and changes depending on the desired behaviors by the research objectives. Transitions are based on user activity, behavior and system time.

actions or promoted desired behaviors were also modeled as states in the diagrams. Then, users' actions and system timings were modeled as transitions between those states. In the user state diagram example we can see black lines that represent user actions, while red transitions represent actions from the other user.

In the user state diagram we can also see some of the behaviors the system adopted to foster social situations. For example, if children did not hunt insects for a certain time, the system would change flock behavior to approach children. Another response was designed for when one user still did not have a creature. In this scenario, one user's creature would wander towards the other user, increasing the chances of sharing the creature.

5.3.3 Final design

The outcome of the design process was a world where three different regions meet: a grass zone with a pond, a deserted zone with little pools of lava and a frozen tundra zone. A cobblestone path crosses through this world (figure 5.1). Efforts were made to create an environment which matched the world described by the children in the PD sessions. The world is covered by a dense layer of virtual fog, which the users can partially open to reveal part of the world which lies below as they wander through the installation (figure 5.2).

For interacting with the virtual environment, users carry a glowing butterfly net, which simultaneously functions as: a cognitive offloader to channel the users attention into the play setting; an object that allows the children to impact the virtual world from the physical world; and an aid for the custom developed tracking system. The environment is populated by swarms of fireflies which can be virtually caught with the butterfly net, utilizing the familiar dynamic of catching insects in a natural manner. Once caught, fireflies change their color to match the one of the user's net who caught them. To discourage competitive behaviors, children can only catch the fireflies which have not yet been caught and have hence not changed color. This prevents users from stealing fireflies which belong to the other user.

As users hunt a sufficient amount of fireflies, these transform into a magical creature which follows the user thereafter (figure 5.3). In Lands of Fog there are a total of 14 creatures that users can discover while playing. Once they appear for the first time, the creatures open a new level of interaction richness with the system. This interactive progression was designed to offer the users an initial simple-to-grasp mechanic that would foster their motivation to explore while at the same time getting acquainted with the system and the environment.

Virtual partners

Once a user has a creature, they can share it with their peer by moving within close proximity, constituting an easy interaction which simplifies the understanding that things can be shared in the world. If users adopt a passive attitude while playing, creatures will try to catch their owner's attention using interesting animations such as greeting their owner. All these creature behaviors were designed to motivate users to remain engaged. Eventually, if users do nothing for a long time, their creatures will even try to move closer to the other user. This behavior is one of the initial mechanics devised for trying to spark socialization behaviors between users during gameplay.

When users' creatures come close to each other, they perform a greeting action towards the other. Therefore, creatures are models of social behaviors for the players, and also try to help children understand that there might be potential interactions between virtual elements. If the two users get even closer, the creatures will perform a choreographed encounter to merge and create new creatures, which take the place of the old ones. This way, children can understand that if they want to discover all the creatures that inhabit the virtual world, they will have to collaborate. Nonetheless, if users keep hunting fireflies without merging their creatures, they will transform the creature by changing its external appearance. Each creature has up to 4 variations, making a total of 56 unique creature alternatives.

Interactive virtual elements

The scenario, or world in which the users play, is not just inhabited by a number of interesting creatures but is also populated by virtual elements which the users can discover while exploring. If a user approaches the virtual elements, their creature will point towards the element and make an exclamatory remark. This way the creature tries to communicate to the child that the element might be a point of interest. Again, these behaviors were devised to encourage the user to explore, and also to promote an inquisitive attitude that would foster socialization between users.

The virtual elements can only be activated when both users bring their creatures close to the element at the same time. When both creatures converge by the object, they will manipulate the virtual element, which will respond with a unique playful animation and then disappear, while the creatures celebrate their discovery. After a while, a new interactive element will appear where the previous virtual element was waiting. This way, only through collaboration users are able to discover all the different interactive virtual elements that populate the magic world.

5.4 Evaluation

5.4.1 Two studies

Over the course of three months, we tested the system with a total of 34 children with ASD in two different European countries. Pilot trials took place in our university in Barcelona, followed by two months of testing in the same location with children with ASD from the area. Next, the system was installed in The Elmgreen School, an inclusive elementary school in London, where schoolchildren from the Special Educational Needs program participated in experimental sessions through the course of one week. We saw that, despite the difference in educational and cultural settings, the system was successful in fostering social behaviors in both contexts, and was received positively by children, parents and school personnel. We describe in the following sections the two experimental procedures where the full-body interactive environment fostered positive social behaviors in children with ASD. We provide full results and a discussion on these in the sections that follow.

5.4.2 Hypotheses

From the defined goals for the research (Section 5.1), three hypotheses were proposed:

1. Children would show motivation to engage in playful experiences in the virtual environment.

2. This full body interactive experience would increase the propensity of each child to engage with other people.

3. Positive social initiation attitudes would be observed between the child with ASD and the neurotypical child during the sharing of the experience.

5.4.3 Ethical validation

The research methodology and protocol was validated by the ethical committee from Universitat Pompeu Fabra in Barcelona, which also validated Barcelona experimental trials. Goldsmiths ethical committee validated the London experiments undertaken at the The Elmgreen School. Parents and caregivers of the children who participated in the experiments were informed through meetings with researchers. Parents were asked to sign informed consents to certify they had been adequately informed and that they agreed with their children participation. Consents informed that the collected data would be anonymous and that participants had the freedom to leave the experiments whenever they wanted. Finally, informed consents also asked for permission regarding dissemination of the results and visual media. Parents of the participants in the PD sessions were also properly informed and were also asked to sign informed consents for their children participation. Children were informed of the activities they were going to undertake and were free to leave whenever they wished, including when they were tired, bored or uninterested by the activity.

5.4.4 Experimental Design

Barcelona

We tested the system with children with ASD recruited by a psychologist from autism centers in Barcelona and the surrounding areas. All of the sessions took place in a large multi-use space at Universitat Pompeu Fabra, Barcelona, where the system was set up. These experimental sessions were preceded by one week of pilot trials, which helped to calibrate the system for young users and finalize the experimental procedure. Pilot trial sessions were followed by an interview with the children who participated to gather feedback on gameplay and design. After the pilot trials, changes were made in the system, including creating a greater sense of anticipation leading up to game events. This was accomplished with additional multisensory elements such as visual and auditory clues, so that children could learn and perform game actions with greater fluency.

Experimental sessions were planned so that children with ASD attended 3 separate sessions, each with a different TD playing partner. Sessions were planned with 5-7 days between sessions, which allowed us to observe changes in social behaviors and willingness to collaborate over time.

London

The game was installed in the multipurpose room of an inclusive elementary school in South London, where a Special Educational Needs unit managed the integration of children with ASD into classes with typically developed children. Over the course of one week, children with ASD were invited by the school experts to participate in "a full-body interaction game where they would hunt for mythical creatures". Sessions were planned into the school timetable, so all testing took place during school hours on the school campus. The approach of the trials in London was specifically different from the approach in Barcelona, as the children only played one session each, stayed in the familiar environment of their school, and were guided by the presence of known school personnel.

5.4.5 Participants

Barcelona

Sixteen male children with HFASD between the ages of 10 to 14 were recruited for this study. The inclusion of only male participants was recommended by the psychologists from Hospital Sant Joan de Déu given that Autism is more prevalent in the male population. A total of six children did not complete the required number of sessions (but four of them did at least one or more sessions), resulting in a final sample size of 10 male children with ASD (N=10). The diagnosis of Autism was determined by the Autism Diagnostic Observation Schedule (ADOS) module 3, which is designed for young people with verbal fluency, with a minimum diagnosed severity of 4. It was decided that verbal fluency would be essential to achieve the level of collaboration required to play the game, so the child with ASD could play without the help of a psychologist or parent. A total of 16 typically developed male children were involved in the project as playing partners for the children with ASD. As a measure to prevent problems playing or comprehending the game, the children with ASD and the typically developed partners were screened for epilepsy and also were required to have an IQ of minimum 70 according to the Wechsler Intelligence Scale for Children (WISC) Wechsler 1949. Due to the large recruitment effort undertaken by the psychologists, the origin of children with ASD showed to belong to a wide range of neighborhoods, socioeconomic levels, and video gaming fluencies as verified during the study through simple questions in the questionnaires administered to parents. It was assured that none of the participants had previously met.

London

A total of 40 children were recruited to participate in a week-long experimental session at the integrated school in London. Of this sample, there were 20 children with ASD and 20 typically developed playing partners, who were all attending the school at the time of the trials. In contrast to Barcelona, most children who participated in the London sessions were from the same neighborhood and educational background. The children were from low to middle income families of southern London, of diverse cultural heritages. The children varied in age from 11-15 years old. As is common with ASD sampling, the majority of participants were male, with 4 female participants with ASD compared to 16 male participants with ASD. Female participants were included since the inclusive school had a gender proportion of female to male participants with ASD which was consistent with the common prevalence of ASD between genders. This way not only could we study the population with the same statistical distribution found in society, but also female students with ASD did not feel discriminated with respect to male students.

The integrated school systematically uses the Social Communication Questionnaire (SCQ) to diagnose the children with ASD. Therefore, we went along with this diagnosis tool in the process of recruiting children of the school for our study. They were attending classes along with typically developed peers, while also participating in targeted educational support and therapy sessions led by the Special Educational Needs unit of the school. A Special Educational Needs teaching assistant of the school was responsible for arranging playing partners, given the criteria that the ASD and TD child pairs would be age-matched, gender-matched, and avoiding the matching of "super partners" (children who were already good friends).

5.4.6 Methods

Data gathering

Barcelona Data was collected through video coding recorded sessions, analysis of system data, and reviewing parents' questionnaires. The video coding scheme used for Barcelona and London experiments was developed in unison with psychologists from Hospital Sant Joan de Déu and the lead psychologist of the research project. The coding scheme was developed for observing social initiations, requests, responses, shared behaviors and gestures. It was based on Pico's Adventure video coding scheme (Appendix A.2), which proved to be valid for coding these social initiation behaviors. Each participant's playing data was recorded in log files during sessions through the use of a player tracking system. This data included information such as child position and game events. Finally, questionnaires were specifically developed for Barcelona experiments (Appendix A.3). The questionnaires were administered to parents the first day and at the end of each session. Parents were asked to evaluate their childs attitude and behavior during each play session as compared to their habitual status.

London Data gathering in London followed an identical procedure to that for Barcelona, with the exception of subjective experience questionnaires which were administered directly to children instead of parents (Appendix A.4). As the children with ASD were attending an inclusive elementary school, school experts confirmed that children would have sufficient cognitive abilities to formulate appropriate responses to one of the experts acting as interviewer. These questionnaires were adapted to the unique experimental format of the inclusive school, given that the children only attended a single session.

To assist in completing the questionnaires, a special educational needs assistant from the school conducted post-session interviews with the children with ASD. The interviews were mainly structured around information related to the children's impression of the game and working with a partner. Example questions included whether the children would return to play the game and whether they felt inclined to get to know their partner better after playing. The assistant had a close relationship with the children, and was able to report on topics such as changes in the child's activity, behavior or flexibility level while playing the game. In addition, we decided that the assistant would be able to guide the children with expressing their opinions. Data was also gathered from typically developed children, who also responded to the same post-session questionnaire.

Data operationalization

The video analysis was performed on 3 minutes video slots using again Lince, like in Pico's Adventure evaluation (Section 4.4.4). As each session would last 15 minutes, the time slots were decided to show the initial moments of gameplay, the middle and the end. In Barcelona there would be a total of 9 video slots for each child, while in London just 3.

Like in the previous project, we also evaluated the reliability between the coders. An initial training was performed until we all reached a good interrater reliability (¿ 0.8). The reliability was again calculated through the ICC.

Session guidelines

The session guidelines were the same for both studies. When entering the room, children were briefly introduced to each other and the people present (the researchers). They were handed the physical pointers and briefly explained how to handle them for a smooth interaction. Once explained they were just told they had to explore the game and that they would be playing together.

Few guidelines for suggestions were made:

- If children do not properly hold the physical pointer, psychologist or researchers will do a physical help to let users better understand how to handle the device.
- If after 5 minutes children have not hunted any insect, they will be first verbally suggested to approach them with their fishing nets. If there is no success from the users, physical help will be applied.
- If 12 minutes have passed and users still have not done any social or collaborative action they will be suggested a series of actions depending on the game state:
  - If just one user has a creature, we will suggest users get together to share it.
  - If both of them have a creature, we will suggest them to get close together to a virtual element.

5.4.7 Procedure

The following procedures were common to both Barcelona and London trials.

Upon arrival to each session, the children were introduced to their partner for the day and had a few minutes to exchange greetings. It was assured that none of the children had a previously established friendship, so that each game provided a unique opportunity for the child with ASD to practice interaction with a new companion. To account for the wide deviation in interaction patterns among children with ASD, experiments were arranged through randomly controlled trials by changing the playing partner for each session in Barcelona.

As the game was designed with an open-ended play format, there was no set end point to the game. Therefore, it was decided after previous pilot trials that the children would play for 15 minutes per session, so the children would have sufficient time to experience all aspects of the interactive setting.

Each experimental session began with an explanation of how to hold the butterfly nets so the system could correctly track the player positions. The children were given minimal directions (such as how to hold the butterfly net for a proper tracking) so that it was their challenge to work out how to play in the experience. This was seen as a way to motivate problem-solving collaborative conversation between the children. Each session concluded with the completion of interview questionnaires regarding the child's behavior and play experience.

5.5 Results

The results were evaluated based upon the system's ability to promote users' engagement and scaffold socialization and collaboration through intelligently sparking interaction in the children with ASD and the TD peers. From these goals, we formed three evaluation criteria. In addition, information was gathered to assess the perception of the system from the perspective of children and school professionals.

5.5.1 Child Motivation

Increase in activity

To evaluate motivation to play, we looked at the activity level of the child during the session, which we considered to be an indicator of whether they seemed to be understanding and willing to engage in active play.

In the laboratory setting, we saw that the distance covered by each child significantly decreased through the sessions (ANOVA: $F(2,9)=45.1$, $p<.001$) (table 5.1), while the amount of hunted insects increased through sessions (ANOVA: $F(2,9)=16.9$, $p<.05$) (table 5.2). As this number of actions increased in correspondence with less distance covered by the children, we understood that the children were beginning to understand the game and engage in purposeful movement. In addition, the player tracking system indicated that the number of seconds remaining still significantly decreased from first to second and third sessions in the laboratory experiments (table 5.3). This also supports the idea that children were demonstrating a consistent willingness to participate in gameplay through the course of the sessions.

Table 5.1: Distance Covered during Sessions

Source	N	M	SD
Session 1	10	35,149.3	1,529.6
Session 2	10	28,947.6	808.0
Session 3	10	20,159.1	1,353.2

Table 5.2: Number of Hunted Fireflies

Source	N	M	SD
Session 1	10	25.2	3.1
Session 2	10	54.5	9.7
Session 3	10	78.3	9.2

Table 5.3: Number of Seconds Still

Source	Z	Sig.
Session 1-1	-2.191	.029
Session 1-3	-2.293	.022
Session 2-3	-.359	.720

Through post-session questionnaires, parents in the laboratory setting evaluated that the activity level of their children significantly increased through the sessions (ANOVA: $F(2,9)=9.559$, $p<.05$) (table 5.4). The special needs assistant in the elementary school concurred with this perspective, noting that 65 per cent of the children showed an increase in their activity level compared to everyday life. This marked increase in activity supports that the virtual environment was a good motivator for children to explore and play.

Table 5.4: Activity Level

Source	N	M	SD
Session 1	10	4.1	3.14
Session 2	10	5.1	3.48
Session 3	10	4.8	3.59

Increase in flexibility

In addition to an increase in activity, in the laboratory tests parents evaluated that the flexibility levels of their children increased through sessions (table 5.5), and the special needs assistant at the school agreed that 70 per cent of the children with ASD showed more flexibility while playing the game than they typically did in other settings such as a school playground, drama class or mathematics class. As individuals with ASD have a tendency to maintain rigid patterns of behavior, this change in flexibility demonstrates a willingness to embrace the games ideals of exploring, sharing and adopting collaborative behaviors.

Table 5.5: Flexibility Level

Source	Z	Sig.
Session 1-1	-2.414	.016
Session 1-3	-2.060	.039
Session 2-3	-1.089	.276

5.5.2 Socialization

In the controlled laboratory experiments, the amount of social initiations from the children with ASD increased through sessions (table 5.6), and the amount of responses by ASD children also increased significantly from the first to the third session (ANOVA: $F(2,9)=8.049$, $p<.05$) (table 5.7). Responses were only considered if they answered a question from another interlocutor using appropriate timing and content. Finally, the total amount of social actions, which was a compound score of initiations, requests, responses and shared actions, significantly increased through the course of the laboratory sessions (table 5.8).

Table 5.6: Number of Social Initiations

Source	Z	Sig.
Session 1-1	-1.569	.117
Session 1-3	-2.810	.005
Session 2-3	-1.899	.058

Table 5.7: Number of Responses by Children with ASD

Source	N	M	SD
Session 1	10	1.9	.504
Session 2	10	3.9	.674
Session 3	10	5.8	1.041

Table 5.8: Total Amount of Social Acts

Source	Z	Sig.
Session 1-1	-1.843	.065
Session 1-3	-2.807	.005
Session 2-3	-2.040	.041

In addition, video coding revealed that an average of 80.4 per cent of social activity during the laboratory and school setting trials was directly related to game events. This means that a majority of the conversation maintained during the game was directly inspired by or related to events occurring in the game. As the game was designed to include interesting and surprising elements, we see that the game served as a successful catalyst for sparking socialization opportunities during play.

The children also showed a tendency towards positive perception of the game as a basis for forming social relationships. In post-session questionnaires from the inclusive elementary school trials, 80 per cent of the children responded that it was easier to get their partner to play as time went on compared to other activities, and 67.5 per cent of children said they believe they would have talked less with their partner in a playground than in the virtual environment.

In addition to creating a comfortable zone for children with ASD to practice social behaviors, we also aimed to provide an opportunity for typically developed children to see that children with ASD could be credible play partners. After playing in the virtual environment, 65 per cent of TD children in the inclusive school indicated that they would like to get to know their partner better after playing together in Lands of Fog.

5.5.3 Collaboration

In the laboratory sessions, we saw that the number of manipulated virtual elements increased through sessions (ANOVA: $F(2,9)=22.9$, $p<.05$) (table 5.9). As these virtual elements could only be manipulated when both partners were working together, we can conclude that the partners were understanding and practicing the benefits of collaborating in the game. We also observed that the mean distance between children decreased significantly through the playing time (T-test: $t(33)=2.119$, $p<.05$) (table 5.10), in both the laboratory experiments and the integrated school experiments. Therefore, as the children were growing more comfortable with their partner in the virtual environment, they were also choosing to play together and share the experience as opposed to playing alone.

Table 5.9: Number of Virtual Elements Manipulated

Source	N	M	SD
Session 1	10	4.5	4.2
Session 2	10	16.1	9.2
Session 3	10	23.5	6.6

Table 5.10: Mean Distance between Children (cms)

Source	N	M	SD
Beginning of Session	34	204.40	55.36
End of Session	34	182.28	57.24

5.5.4 Perception

When asked about their perception of the game, 95 per cent of the children at the elementary school responded positively to the idea of playing again. We asked the children to compare the experience of playing in the game to other school activities. From this, 95 per cent of children with ASD said they had enjoyed playing with their partner more in Lands of Fog than they would have in physical education, and 70 per cent of children reported that they had enjoyed working with their partner more in the game than they would have in a science practical. We also found that children with ASD enjoyed significantly higher working with the partner than typically developed children in the game than in Physical Education (Wilcoxon: $Z = -2.44$, $p<.05$), which could be an indicator that the game is less daunting compared to other playful activities.

5.6 Conclusions & Discussion

Results show that Lands of Fog was successful on motivating users to engage with the system, while also fostering social and collaborative behaviors between players. Moreover, parent, professional and user feedback shows that the game was well received.

We believe that Lands of Fog demonstrates the potential of technology to design systems which can be deployed in special education centers and inclusive schools as intervention tools, and also as aids for social inclusion for children with ASD.

5.6.1 Potentialities for therapy

We can see in the results an increase of purposeful activity through sessions in the laboratory controlled trials reflecting that users' activity became more focused as they learned how to interact with the system. These results seem to indicate that the addition of a simple initial mechanic, such as hunting fireflies, was a successful design strategy to help children get acquainted with the system. Furthermore, the subtle introduction of richer mechanics through play seems to have helped children to flow from the more individual and simple mechanics, to the collaborative ones such as merging or manipulating virtual elements. This seems to be in consonance with what Davis et al. proposed Davis et al. 2010. This results are in consonance with the results obtained with Pico's Adventure evaluation (Section 4.5).

In the laboratory trials, we wanted to have a controlled setting which would allow for assessment of the system's goals of user motivation, socialization, and collaboration. The fact that the children showed improvements in these areas through the course of multiple sessions indicates the system's potential as a tool for intervention or therapy. Social therapy approaches for children with ASD require a large degree of dedication from trained therapists. Therefore, providing controlled systems which are programmed to adapt to changes in children's behavior could assist therapists by providing consistent and immediate support, thus lowering the therapists' individual workload. The positive findings with Lands of Fog as a system to scaffold behavior seem to be in consonance with other projects using virtual environments to teach social behaviors, as presented in the State of the Art Casas et al. 2012; Cheng and Ye 2010; Porayska-Pomsta et al. 2011 (Section 2.3).

The data analysis showed a significant increase in the number of environmental elements manipulated by the players. As environmental elements were only able to be activated in collaboration with the other player, the players had to communicate amongst themselves and decide on a unified plan of action. Another variable that could have demonstrated positive social interaction was the number of times that the players merged their creatures which increased in the laboratory trials from 5.2 in the first session to 6.7 in the third session of the laboratory trials. This interesting game mechanic was also a good motivator for children to work together for a common goal, discover all the creatures.

The fact that environmental element manipulations and creature mergings were occurring consistently throughout the sessions shows a presence of collaboration behaviors, and the significant increase in the occurrence of these indicates the games potential to foster positive social interaction attitudes.

5.6.2 Possibilities for school implementation

After testing the functionality of the system in a controlled laboratory environment, we assessed the deployment of the system in an elementary school. One of our goals for these sessions was to determine the reception by the school community after one week of experimental trials.

At the end of the week, faculty members and any children who had participated were invited to an informal information session, where they gave their opinions and interpretations of the game. At this point, we saw that there was a wide range of narratives that the children had formed as a result of the open nature of the game. During the information session, we saw that the children were eager to share their experiences with one another, and the school faculty commented on the rich mixture of children who were interacting outside of their normal social groups as a result of a new shared experience with Lands of Fog.

During the trials, we also saw that the game served as a way to mediate socialization between individuals who had not met before or were just school

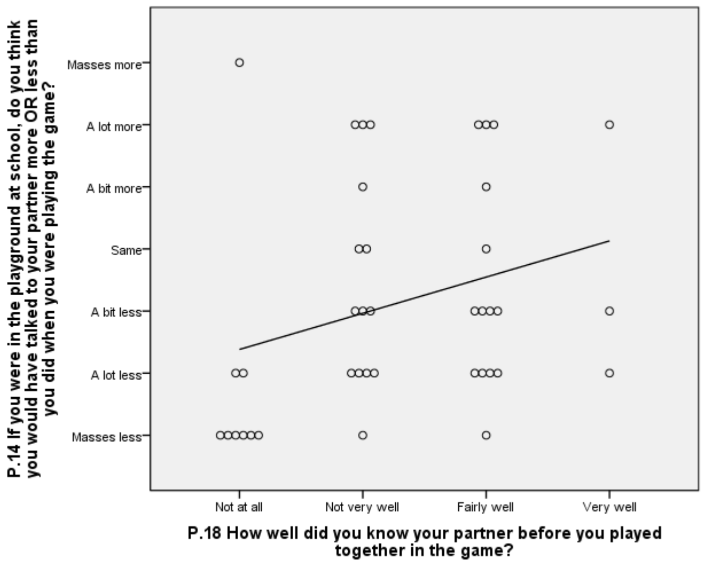

Figure 5.5: Scatter plot correlating answers to how much children knew their partner to if they thought they would have talked more to their partner in the playground than in the game.

acquaintances. The video coding results show us that the game served as a solid helper since a high rate of social bids were directly related to the game events and elements. We saw that not only did children who met for the first time enjoy the experience of playing together, but also the school students who knew each other but had no friendship had a good time too. Moreover, we saw that the less they knew their partner prior to playing, the more they saw the game as a useful scenario to facilitate conversation when compared to playground time (figure 5.5), with a Pearson correlation = 0.29, p=.073 (2-sided). Despite the low Pearson correlation we see a positive tendency which needs to be further explored. As fragmentation of social relationships occurs at a higher rate among children with ASD, installations such as Lands of Fog could be useful additions to school settings to unite students through an enjoyable common experience. These kinds of settings could be useful to provide support during unstructured social scenarios as Anderson proposed Anderson et al. 2015.

Given Pico's Adventure (Chapter 4) and Lands of Fog outcomes, we believe that while developing systems for individuals with special needs, it is important to take them into account as design informants and work closely with professionals for developing a successful installation.

According to post-session questionnaires, children with ASD at the inclusive elementary school found it easier to form social bonds (the basis of social relationships) when playing in Lands of Fog, as compared to typical school settings like PE or science class. Typically developed children also enjoyed the experience of playing with Lands of Fog, and furthermore the majority viewed their partner with ASD as a valuable colleague and expressed their desire to get to know their partner better after playing.

This project represents the first time that such an ICT approach has been used, given that it uses full-body interaction applied for a multi-user experience to foster social initiation behaviors in ASD children. Taking into account the characteristics of the system where users are present and able to socialize in a collocated environment, we believe results prove the benefits of such an approach and the potential of similar technologies based on embodied cognition theories. This opens a number of previously uncertain doors for new future research and exploration.

Finally, the timeline of trials at the inclusive school allowed each child to play in the game for a single session. Given the positive results across multiple sessions from the laboratory trials, we believe that the permanent presence of this type of installation in an inclusive school environment would be useful in strengthening the social relationships between members of the school community. Nonetheless, we believe that a longitudinal assessment of the system in an inclusive school setting must be conducted to further assess the potentials of such tools. It could also be interesting to assess in the future the potential impacts of such a novel tool in a Special Education center or Inclusive School, given that it could reshape how children perceive playtime activities.

Moreover, although it was not statistically significant, we observed some playing differences between male and female participants in London, as females tended to show less engagement at the beginning of play. This could be related to the fact that the Participatory Design sessions consisted of only male participants. Further research must focus on the gender distribution during PD and how it affects acceptance of the final design by both genders.

Chapter 6

Full-body interaction analysis

In the previous chapters, we have presented three different approaches to full-body interaction, from both an interaction design approach and evaluation perspective. In this chapter, we will first make a summary of the contributions from the different systems from an interaction design perspective in Section 6.1. From this summary, we will start to draw commonalities between the three different approaches by comparing their characteristics given a series of categories (Section 6.2). This will allow us to start formulating a series of guidelines for the design of full-body interaction systems for children with ASD, aiming at promoting social initiation. These guidelines are presented in Section 6.3. We believe it is important to explain that, although we have tested different media approaches, and some results seem to be coherent from a HCI point of view, it is fundamental to understand that the technology itself has no specific benefits unless designers and developers understand its advantages and how to use them. We must understand these experiences and contributions from an holistic perspective taking into account goals, design, development and evaluation all together.

6.1 Individual projects contributions

6.1.1 SIIMTA

With SIIMTA we tried to explore the benefits of full-body interaction to develop a MT installation for children with LFASD. The main aim was to promote engagement by fostering exploration, which was understood as a diversification of movement. Although we could not validate our hypothesis, the project throws some interesting results, which can be taken into account for further development of new EI systems.

Interface

SIIMTA was designed as a first-person interaction paradigm installation. This paradigm has some unique advantages, such as users being more close to the display, hence to the digital content. This allows for a 1:1 relation of users with the virtual environment, translated into what can be understood as a direct interaction of their body with the virtual objects (Parés and Altimira 2013). In their Virtual Subjectiveness model, Pares and Pares (Parés and Parés 2006) talk that the relationship between the virtual content and the physical interfaces, are the mappings. These mappings define how the user perceives the experience. Thus, creating a system where users have a 1:1 relation to the virtual environment allows for a more natural and easy to grasp experience. We believe this approach helped children with LFASD adapt quicker to the new experience, which resulted into a 0% dropout of users during the experimental assessment related to rejection (Section 3.4.5). Moreover, this interaction paradigm seemed more adequate for the objective population, as children with LFASD tend to show higher challenges in motor skills (Section 2.1). Giving them a more natural interaction could have helped them to easily interact with the system.

The use of a vertical large surface also brought some interesting observations. The screen used during the experiments was based on an elastic fabric specific for retro projection. In the experimental sessions, we observed that during the first sessions a high amount of children got close to the screen and experimented with the screen by caressing or pushing it. This is in consonance with what was presented in Section 2.1.2 on how children with ASD may explore objects and toys through caress (Williams 2003; Rowland and Schweigert 2009). Children with ASD have difficulties in sensory processing, being normally over- or under-reactive to stimulation (Lane et al. 2010). Although we have no specific recordings of this, as session recordings were just based on silhouette (for anonymization and interaction), we assumed, after a discussion with the present psychologist and caregiver during experiments, that these behaviors seemed to be a sensory approach for modulating their experience with a new system and scenario. We must be really humble with this observations, as this was not the scope of our experimental evaluation and they were just field observations, but for future systems it might be interesting to pay special attention to the materials used and their affordances.

The physical interface we used for the system, based on a 2D camera and an IR light, was suitable for the desired movement interactions. Nonetheless, as we have described in the procedures section for SIIMTA (Section 3.4.5), the way the tracking system worked made it really sensible to diversions to the guidelines, which lead to many corrupted registers. We believe that from this experience we can suggest that when working with users who have challenges on self regulation (Gabriels et al. 2005; Johnson and Myers 2007), as we have seen in Section 2.1.1, it is mandatory to develop technological solutions easier to calibrate and more error safe. In the case of SIIMTA this could have been achieved by not requiring an initial empty frame (i.e. with nobody in front of the camera), which could have helped caregivers conducting the sessions to start easier each play session while also having to control the three children in the room. Another solution could have been to give more on screen visual queues before starting the session in order to assume that the guidelines were being followed properly and the system was properly calibrated.

Content design

Another contribution we would like to comment is the use of abstract visual content for the installation (Section 3.3). We adopted this design approach from MEDIATE's experience to avoid any kind of adverse reaction of users towards the application content (Parés et al.). During the evaluation, we did not directly ask children whether they liked the visuals or not, something which was discarded because children with LFASD tend to show severe difficulties with communication or no language skills (Section 2.1). Nonetheless, again none of the dropouts were given by a direct rejection of the children towards the content. Moreover, after a discussion with the caregivers at the end of the experiments, we presumed that part of the sensory stimulation children sought with the screen was guided by the virtual particles.

Evaluation

Finally, as we commented in Section 3.6, the operationalizations defined for analyzing the registered data (Section 3.4.4) by the system might not have been the best way on approaching the data analysis. Both in M4ALL (Chapter 4) and In-Autis-Tic (Chapter 5) research projects, before the final experiments, a series of prototype trials were made for assessing the viability of the developed installation and do some final improvements. This approach also allowed us to test the experimental methodology, from sessions' time, to data gathering methods. We believe SIIMTA research would have greatly benefited of following a similar process, so we could have assessed our evaluation methodology before applying it.

6.1.2 Pico's Adventure

We developed Pico's Adventure as our approach to the "Motion-based adaptable playful learning experiences for children with motor and intellectual disabilities" European research project. As mentioned in Chapter 4, the system used the Microsoft Kinect camera and was aimed at promoting social initiation behaviors.

Interface

For Pico's Adventure we adopted a different point of view paradigm. As we wanted children to put into practice some social skills, such as stimuli discrimination or joint attention, the technology chosen to implement the video game was the Microsoft Kinect, a camera that allows for gesture, position and movement tracking. The use of this camera, which has to be placed in front of the TV facing away the screen, forced us to adopt the third-person interaction paradigm (Parés and Altimira 2013) and represent the user in the virtual environment by rendering their captured image. This approach is forcing the user to stand away from the display. Thus, a virtual representation of the user's body within the VE is necessary as part of the interaction feedback, which further leads to an indirect interaction with the virtual objects (Parés and Altimira 2013). With this configuration users have to go through a first process of understanding the mapping between their actions and their virtual representation, and their relation with the virtual environment. During the experiments, we perceived some difficulties for the young children with ASD to understand the relation of their activity with what was happening into the screen. Nonetheless, some of the problems were derived from the expectations of the children of the system being a multi-touch device. We believe this was expected, given the raise on the use of this devices in the last years and its increasing use for individuals with developmental disabilities (Stephenson and Limbrick 2015). This raised situations were children tried to get close to the screen and touch the virtual agent or the interactive elements. This was a challenge for the tracking system, as it expected users to be at a minimum distance of 2 meters. With this situation, we would like to say that it is important to take into account the affordances and physical constraints of the technology in use.

Moreover, the third-person paradigm brought another interesting scenario. During the PD sessions, a child refused to play because he was being displayed in the screen by our third-person approach, like if it was a mirror. When we talked with his parents, they reported that their child did not like to see himself reflected in mirrors. For solving this situation, we adapted the game so it would be possible to configure whether the virtual representation of the user was their captured image, or just their silhouette in a gray color. With this solution the child was able to collaborate through all the sessions during the PD and when he was invited in the pilot trials.

Finally, results have shown that mostly non-integrated social initiations were promoted (Section 4.5). Although being coherent with autism literature related to difficulties of individuals with ASD in integrating their social initiations with gaze directed to the interlocutor (Koegel and Frea 1993), these results also raise relevant research questions related to the physical constraints of the used interface. The Microsoft Kinect based configuration could have played a role in limiting the amount of gaze physically directed toward the other player, as players are required to be one next each other and looking at the TV. Moreover users can “see” their peer on screen and maybe they use their peer’s virtual image as an objective of the directed gaze. Thus, it is important to understand which kind of behaviors is going to promote the physical interface chosen when designing systems to foster socialization. In our case, having chosen an interface which might be hindering gaze integration in social initiations, might lead to worse outcomes for users, as gaze integration is pivotal to a proper development of social communication behaviors (Frischen et al. 2007).

Interaction design

We believe that adopting Davis et al (Davis et al. 2010) design strategy of starting an interactive experience with simple to grasp mechanics, allowed us to develop a first session which helped users to both understand more easily how the interaction worked and to quickly develop the mental understanding of the mapping between their physical actions and the virtual actions. We did not have any dropout related to difficulties on understanding the game.

Moreover, during the first session we improved the interaction approach with the sudden introduction of an unexpected antagonist. This lead to a significant improvement on social commentaries by users (Table 4.14 in Section 4.6). Alcorn et al. suggest the use of unexpected audiovisual content to foster social initiations (Alcorn et al. 2014). An approach of using events that violate the learned rules of the virtual environment seems to contradict the supposed benefits of the high level of predictability offered by technological solutions. Our contribution of what seems a contradiction is that we, as interaction designers, must always thoroughly think about which strategies we adopt to achieve our goals. In this specific design we see how it is possible to search for a balance between exploiting the potential of technology of being predictable, with the challenging idea of subtly introducing unexpected situations to children with ASD.

Yet another design strategy we have put into practice are the peepholes, understood as artifacts that provide a limited view into a large space (Dalsgaard and Dindler 2014). This strategy proved to be an effective resource for promoting exploration in the second session of Pico's Adventure. After comparing the first session and the second, we observed a tendency for less repetitive behaviors, characteristic of individuals with ASD (Section 2.1). We have seen that this design strategy has lead to positive results both in Pico's Adventure (Section 4.6.4) and in Lands of Fog (Section 5.6).

We have also seen from the obtained results that not all interaction design decisions were successful. As presented in the conclusions section for Pico's Adventure (Section 4.6) the gameplay where two users had to hold hands for capturing falling starts was not eliciting the behaviors desired. We believe that the proposed game mechanic allowed children with ASD to easily substitute verbal communication for an instrumental use of the other player. This results indicate that when designing for eliciting social initiation, game mechanics which can foster instrumental use of the other should be avoided.

Content design

Another contribution we would like to comment from Pico's Adventure experience is that, although literature on ICT for individuals with ASD normally suggests a high configuration and personalization of the system for each patient (Bartoli et al. 2014), we believe this does not exactly mean that all visual content should be specifically configured for each child. In Pico's Adventure our approach for customization of the experience for each user was through allowing children with ASD to configure their virtual peer as they wanted by exploring and putting into practice the social skills we desired to foster. We believe this approach allows for personalization of the experience without hindering the overall quality of the audiovisual content displayed, as all content has been designed to be in cohesion by a professional designer.

Finally, we would like to talk about the idea of guiding all the experience through a defined narrative. The specification of a narrative arch, based on literature of story structure (Section 4.3.2), helped to properly divide the different goals of the installation and offer a nice learning curve to the users. Pico's Adventure was the first installation we developed that had a world rationale in the experience. We discarded the perspective of using abstract content, with no developing narrative arch, to embrace a more adventure based and realistic style. This approach also allowed to clearly define scenarios that would elicit more specific behaviors. For example, giving children a superpower such as a magic ray from their hand, properly promoted pointing behaviors related to joint attention. As we can see in the results, the principal verbal interactions were related to directive acts, such as requests and instructions aimed toward causing the listener to make some particular action or calling their attention, or expressive acts, such as commentaries on game elements, aimed at expressing their attitude toward a particular object or event.

6.1.3 Lands of Fog

We have previously explained that the last system we designed, developed and assessed, Lands of Fog, was a multi-user full-body interaction environment based on a large-scale floor projection, 6 meters diameter, where two users play together. The system was geared towards promoting engagement, socialization and collaboration. We will now present the contributions of the system compared to the previous approaches. We followed SIIMTA's similar design approach, by stripping out all content and stick to the interaction principles from a previous experience (Section 3.3), in this case Lightpools (Hoberman et al. 1999). Nonetheless, it is important to clarify that many interaction design principles were modified, taken away or added.

Interface

After exploring the possibilities of a third-person paradigm with Pico's Adventure, we went back to a first-person interaction paradigm (Parés and Altimira 2013). In this case, rather than using a large vertical screen, like in SIIMTA, we used a large-scale floor projection, so users could wander around the virtual environment in a 1:1 fashion, like in Lightpools (Hoberman et al. 1999). We believed that the use of a non-vertical screen could foster better integrated socializations, as it would be more natural for users to first look at the floor and then to their colleagues. This way, we could counter the results seen in Pico's Adventure of most social initiations being non-integrated.

Results we obtained from Lands of Fog video coding do still show that in general, more non-integrated socializations were taking place than integrated ones. Although the difference was smaller, we cannot say it was thanks to the technology in use, as both experiments differ on game play and population. We suggest further research on how to develop systems that foster integrated socialization, given its benefits (Frischen et al. 2007). We believe that starting from a floor projection is recommended as it is a configuration that resembles playgrounds and gives users the option to quickly raise their gaze to search for their peer. Nonetheless, we suggest that future research should focus on the development of interaction strategies based on displaying specific content in users heads, thus forcing them to have to look at their peers head for playing together.

Another difference with SIIMTA and Pico's Adventrue is that, in Lands of Fog, users use a handheld pointer to interact with the virtual environment. The idea of using a pointer was also inherited from the Lightpools system (Hoberman et al. 1999). The pointer, with the shape of a butterfly net, was used for both the tracking of user's actions, but also as a cognitive offloader. As interaction would be happening below users, we assumed that having a pointer would help users to better focus to the action, but moreover, let them bring it where they wanted, as they could move the pointer freely around their body.

As aforementioned, the use of a large space as the interaction environment was inherited from the Lightpools design. This physical configuration allows for having more than one user at the same time enjoying the experience. If we want to develop VEs, where users can put into practice social communication skills, we believe it is beneficial to offer spaces with more natural settings, by having collocated users in the same physical space and not making technology a mediator of the communication process. Moreover, we think that using large-scale spaces is a good approach, as it gives users the possibility to have their own space, and helps them, whenever needed, to freely auto-regulate themselves. De Jaegher suggests that if cognition is based in participatory sense-making, the creation of technological spaces that allow for an optimal flow of interaction is necessary. But as social interaction and sensorimotor capacities might be different between individuals with ASD and TD people, it is mandatory that these spaces allow for users with ASD to have their interaction freedom for self regulation (De Jaegher 2013).

Interaction design

For the design of Lands of Fog, we also adopted the interaction strategy of implementing an initially simple to understand mechanic for motivating individuals with ASD engagement with the system, suggested by Davis et al. (Davis et al. 2010). We also wanted to take advantage of what Micheal S. Horn calls cultural forms; the idea of designing situations that evoke cultural forms as a way to use user's cognitive, physical and emotional resources (Horn 2013). Thus, the initial mechanic for grasping user's attention in our design was hunting a series of fireflies that would be wandering around the virtual environment. As users have a butterfly net as the mean to interact with the world, we wanted users to understand what they could do by relying on the cultural form of the butterfly net (i.e. hunting insects).

We used again the peepholes design strategy (Dalsgaard and Dindler 2014). In this case the technique was implemented by covering the whole virtual environment with a dense layer of fog (Section 5.2). We can see in the results that the amount of distance moved between the three sessions in Barcelona experiments, decreased significantly from first to the third session. Although this might be interpreted as a decrease of user's activity throughout sessions, the amount of individual and collaborative actions increase from session to session (Section 5.5). This makes us believe that the peephole mechanic was really effective on fostering children to explore during the first session, thus fostering engagement and motivating them to actively participate to discover what the fog was hiding. We understand the decrease on the amount of distance covered by the users as a familiarization with the VE, thus, as a specialization on the use of the system, making their movement more specific to their desired actions.

Another contribution we want to comment is our approach into how to encourage collaboration. Previous literature has suggested the idea of "enforced collaboration" (Ben-Sasson et al. 2013). This strategy seemed to foster a higher degree of socialization, but also of frustration. Our approach to motivate collaboration in Lands of Fog is what we call "encouraged collaboration". Rather than forcing the collaboration to advance in the experience, we build a game where users can collaborate to achieve higher degree of interactions and audiovisual feedback, but that in any moment they can go back to simple solo mechanics to play by their own if they want. In this way, we are still fostering socialization and collaboration between our users, but still giving their space as De Jaegher suggests for an optimal flow of the experience (De Jaegher 2013).

Content design

We previously discussed the advantages of having a system with a narrative structure and specific realistic content to better differentiate the different goals of the project. For Lands of Fog, we also aimed for a more realistic or representative content. The virtual world was based on different recognizable regions. Moreover, the creatures, although not being representations of real ones, were based on the PD sessions and were really similar to those from known videogames, movies and books. But in this case, the system was designed as an open-ended experience without a clear objective. In Lands of Fog, we wanted the users to discover the range of possible actions by exploring and having to discuss between the users. In this way, we assured that the narrative of the experience emerged from users personal shared experience with the environment. We observed that different play couples created different rationales to their actions. Children, not only collaborated for achieving something in the environment, but they also collaborated in order to understand it. We believe that allowing the children to freely explore and understand the virtual environment is a good way of letting them interact with the system in their own pace, but moreover, we are encouraging a higher level of collaboration going further than juts the physical coordinated actions.

6.2 Common contributions

After the summary of the contributions we reviewed from the three different systems, now we will present them in a series of tables, which categorize the different contributions and results through different topics, such as goals, interaction design, technology or evaluation. This will better help the reader to grasp the differences and commonalities between the different systems we have presented in this thesis.

The categories are as follows:

- Research goals
- Interface
  - Physycal setting

  - Interaction paradigm
- Interaction design
- Design methods
- Content design
- Evaluation
  - Assessment methods
  - Procedures
- Results

6.2.1 Research goals

We developed the Table 6.1 to categorize the three different projects we have presented given their research goals. The categories are based on the objectives of motivation and social initiation we pursued in this Thesis.

	SIIMTA	M4ALL	In-Autis-Tic
Foster engagement	Yes		Yes
Encourage exploration	Yes	One session	Yes
Promote socialization		Yes	Yes
Elicit collaboration		Some sessions	Yes

Table 6.1: Research goals

We separate motivation between engagement and exploration. Exploration is understood as an interaction approach where a higher degree of engagement is pursued. By promoting exploration, we keep users active in the environment and elicit social initiations through promoting requests from users when searching. We have divided social initiation into plain socialization and collaboration, which is understood as a higher level of socialization based on a common goal between the users.

	SIIMTA	M4ALL	In-Autis-Tic
Large surface	Yes		Yes
Small surface		Yes	
Vertical display	Yes	Yes	
Horizontal display			Yes
Hanheld pointer			Yes
Touch	Not intentionally		
2D camera	Yes		Yes
3D camera		Yes	

Table 6.2: Physical setting

6.2.2 Physical setting

The "physical setting" table (Table 6.2) is focused on categorizing the characteristics of the physical interface used in the projects we have presented.

We can see that in this Thesis we have explored a wide range of different physical configurations. We have explored the use of large space systems both for single and collocated experiences. With Pico's Adventure we also explored the use of a collocated system, but in a small format (Chapter 4). We have seen how the spatial configuration of the interactive system can affect users behavior. We believe large-scale spaces grant children with ASD the freedom to decide their gameplay style while playing in regards to their peer. Thus, we suggest to use these categories as a checklist when designers specify the physical interface.

The Table 6.2 also reflects the unexpected exploration behaviors of children playing with SIIMTA (Chapter 3), which suggests that designers must reflect on the physical properties of the interfaces in use.

6.2.3 Interaction paradigms

In Table 6.3 we list the interaction paradigms we have explored in our research. We categorize our projects depending on the point of view of the

	SIIMTA	M4ALL	In-Autis-Tic
First-person	Yes		Yes
Third-person		Yes	
Manipulative interaction	Yes		
Contributive interaction		Yes	Yes

Table 6.3: Interaction paradigms

experience and the level of interaction users can achieve with the virtual environment.

We have previously discussed the potential benefits and drawbacks of first-person and third-person experiences. It is important to understand the impact of different interaction paradigms in users when designing systems as aid tools for intervention for people with special needs. As designers we must build systems which are engaging for the users, so dropouts are avoided from burden or boredom.

6.2.4 Interaction design

The "interaction design" table is focused on the different interaction design strategies we have used in our research for designing the gameplay of the three full-body interaction systems. The table is divided in different strategies, such as the peepholes or the simple initial mechanic. Moreover, we have added interaction approaches based on specific social initiation skills, such as stimuli discrimination and joint-attention.

We suggest the use of Table 6.4 as a checklist for interaction designers when working in new projects. In Section 6.3, we present a series of design guidelines based on our research. With our guidelines, and knowing the goals of the project, we suggest that designers could select which interaction strategies they could implement in their systems to achieve goals related to motivation and social initiation. For example, if a system must promote

	SIIMTA	M4ALL	In-Autis-Tic
Movement based	Yes		
Exploration sections	Yes	Yes	Yes
Cultural forms			Yes
Peephole		Yes	Yes
Simple initial mechanic	All interaction	Yes	Yes
Unexpected situations		Yes	Yes
Stimuli discrimination	Yes	Yes	Yes
Joint-attention		Yes	
Turn-taking		Yes	
Collaboration		Yes	Yes

Table 6.4: Interaction design

engagement, designers could mark the peephole category as an interaction design approach to embed in their design.

6.2.5 Design methods

Table 6.5 lists a series of standard methodologies in research. From our experience, we suggest the use of all these design methodologies. For Frauenberger et al., when target population is included as informants in the design process, the understanding of the requirements specific to that population is increased (Frauenberger et al. 2012). Furthermore, we have listed the use of Prototype Trials to also make explicit the problems we had with SIIMTA's research methodology (Section 3.6).

	SIIMTA	M4ALL	In-Autis-Tic
Meetings with stakeholders	Yes	Yes	Yes
Participatory design		Yes	Yes
Prototype Trials		Yes	Yes

Table 6.5: Design methods

6.2.6 Content design

When designing full-body interaction systems, we must take into account which will be the experience the users will undergo. Table 6.6 lists the different approaches we have explored with the projects presented.

We can see that we have explored both a completely abstract approach and two narrative-based experiences. In the Limitations and Future work (Section 7.1) we discuss which could be the implications of different approaches on content design.

6.2.7 Assessment

We have grouped in a table all the criteria related to evaluation that has been explored in the three presented projects (Table 6.7). The categories are based on population, hypotheses and data gathering methods.

We classify population between low-functioning and high-functioning ASD. Depending on the target population, designers can expect different motor and social abilities from the users. For example, when designing SIIMTA, we went for an easy to understand interaction and a first-person approach to help the children with LFASD to quickly grasp the gameplay (Chapter 3). In Pico's Adventure, given the population functioning level, we were able to design mechanics that required vocalization (Chapter 4). Designers must understand, through meetings with psychologist, caregivers and families, which are the abilities they can strive for in the design of new experiences.

The last three categories represent the three different tools we have used to evaluate our systems. From our experience, we suggest that for evaluating

	SIIMTA	M4ALL	In-Autis-Tic
Abstract content	Yes		
Specific content		Yes	Yes
Narrative structure		Yes	Emergent

Table 6.6: Content design

	SIIMTA	M4ALL	In-Autis-Tic
LFASD	Yes		
HFASD		Mid-high	Yes
Engagement	Yes		Yes
Socialization		Yes	Yes
Collaboration		Yes	Yes
Young children		Yes	
Early teenagers	Yes		Yes
Questionnaires		Yes	Yes
Video coding		Yes	Yes
System data	Yes		Yes

Table 6.7: Assessment

full-body interaction systems all three tools are valuable. Questionnaires can be used both for users and family/caregivers input. Moreover, when working with systems where social initiation behaviors are put into practice, the use of video recording and coding allows for a more qualitative observation of user's activity.

6.2.8 Procedure

Table 6.8 summarizes the procedures we undertook for the evaluation of the three projects presented in this Thesis. We can see that it is common to have psychologists and family/caregivers present in the experimental sessions. Both in Pico's Adventure (Chapter 4) and Lands of Fog (Chapter 5), parents presence was suggested by psychologists to be social "objectives".

We can see in the "procedure" table that we have tested our systems both in natural settings and controlled laboratory settings. Our approach to the evaluation of full-body interaction media as intervention tools for children with ASD has been from an interaction design perspective. Thus, we have done short experimental procedures to evaluate mainly how interaction design affected user's activity and behavior.

	SIIMTA	M4ALL	In-Autis-Tic
Specialist present	Yes	Yes	Yes
Other peers present	Yes	Last session	Unknown peer
Family present		Yes	Barcelona
Controlled laboratory experiments		Yes	Yes
Natural setting experiments	Yes		Yes
One session			London
Multiple sessions	Yes	Yes	Barcelona
Playing alone	Yes	First session	
Playing with known partner		Family	London
Playing with unknown partner		Yes	Barcelona
Repeated measures	Yes		Yes
Randomly distributed		Yes	Yes

Table 6.8: Procedure

6.2.9 Results

In the Table 6.9 we summarize in which goals our systems have been successful. The objectives are both based on motivation and social initiation.

	SIIMTA	M4ALL	In-Autis-Tic
Engagement	Yes	Indirect	Yes
Interaction diversification	Yes		Yes
Socialization		Yes	Yes
Collaboration		Not explicit	Yes

Table 6.9: Results

We believe that the presented tables can be a tool for exploring the characteristics of different full-body interaction systems for the promotion of engagement and social behaviors in children with ASD. Moreover, with the guidelines presented in the Section 6.3, the tables could be used as a checklist of design criteria or strategies to follow when developing and evaluating new full-body interaction experiences.

6.3 Suggested guidelines

Through all three research studies, we have explored a series of characteristics of full-body interaction media that are advantageous over other interaction media for the development of novel experiences for children with ASD aimed at promoting engagement and social interaction. Children with ASD face a variation of challenges given their condition, mainly related to social interaction. These challenges include impairments in social communication skills and difficulties initiating social interaction by themselves. One of the consequences is that children with ASD might find challenging forming and maintaining relationships with peers, which leads to social fragmentation. It is fundamental to develop systems which help children to put into practice the social skills they have learned from therapy, and we believe full-body interaction is a suitable technological approach for this goal.

First-person interaction

When designing full-body interaction one can develop systems with a first-person or a third person-paradigm (Parés and Altimira 2013). For developing systems for children with ASD with the objective of promoting engagement and socialization, we suggest the use of the first-person approach. With this approach, users have a 1:1 relation with the virtual environment, which leads to a more natural and less cognitive heavy experience. Users can directly understand the mappings of their activity with the digital world, avoiding having to go through a learning phase of how they are represented in the virtual environment. Moreover, if designers use a handheld pointer device for interaction, we suggest that they try to design it so the cultural form (Horn 2013) of the object helps children with ASD understand which is its use in the interactive environment. Finally, we would like to clarify that we do not fully reject the third-person paradigm. We suggest that if interaction designers want to use this approach, they need to thoroughly evaluate the advantages against the inconveniences. Furthermore, we suggest the use of trials to really understand how the physical interface configuration is understood and adopted by users.

Initial interaction steps

We encourage the design guideline suggested by Davis et al. (Davis et al. 2010) of using an initial, easy to understand and repetitive mechanic when designing systems for children with ASD. By developing an initial mechanic that is easy to grasp, children have the opportunity to quickly understand the initial steps of the game, avoiding rejection by complexity. Moreover, making this mechanic repetitive, but contributing to the gameplay, we can take advantage of why individuals with ASD have an affinity towards ICT, that is its predicatbility and discretedness (Brown and Murray 2001). Nonetheless, we encourage the use of subtle and sporadic introduction of unexpected feedback to user's actions, as suggested by Alcorn et al. (Alcorn et al. 2014), to scaffold new scenarios, keep users engaged and motivate and promote social initiations.

Peepholes

If the system has to encourage engagement and exploration, we suggest the use of the peepholes design strategy presented by Dalsgaard and Dindler (Dalsgaard and Dindler 2014). Peepholes are virtual objects that limit the view of the environment to the user. This design approach is really suitable to promote exploration, thus to promote active engagement of the user with the virtual environment. We suggest that designers use this approach always embedded in the rationale of the virtual environment, such as having a dark scenario where users can cast a little point light to illuminate the environment, like in Pico's Adventure (Chapter 4), or a world covered by a dense fog, like in Lands of Fog (Chapter 5).

Collocated environment

Research suggests that children with ASD prefer activities with peers rather than directions through digital media (Bottema-Beutel et al. 2015). For systems geared to promote social behaviors, we suggest the design of multi-user environments with a collocated approach. Thus, we understand it is important to offer experiences where users can practice social behaviors with other people through direct communication. Full-body interaction systems are suitable for this, as they are experiences where users can be physically located in the virtual environment. We believe that systems must be build as scaffolds of natural socialization. Moreover, we encourage the design of full-body interaction systems on large spaces, where children with ASD have their physical freedom to auto-regulate (De Jaegher 2013).

Encouraged collaboration

To collaborate, it is necessary to agree on a common goal and how to approach it. Thus, we suggest to gradually introduce users to more complex mechanics that demand from them to socially interact. In contrast to the enforced collaboration approach presented by Ben-Sasson et al. (Ben-Sasson et al. 2013), we suggest an non-blocking experience approach where collaboration mechanics are available in parallel to playing alone. Interaction designers have the responsibility to make the collaborative mechanics more rewarding than solitary play. We suggest this coexistence of solitary and collaborative mechanics as a way of giving freedom to users to engage in the gameplay they want.

Video coding to evaluate socialization

We suggest that for the evaluation of full-body interactive experiences for promoting social initiation behaviors, video record the sessions and apply video coding as assessment method. ICT allows for a discrete recording of the different events that take place during sessions with the tool. This information is really valuable to quantify the amount of occurrences that different actions have taken. Nonetheless, when evaluating systems aimed at fostering social behaviors, we need to be able to also assess the quality of these social interactions. Recording and coding the experimental sessions allow for observing the quality of the social skills applied. This has been really useful method in this research that helped us understand which are the idiosyncrasies of different physical interfaces. For example, in Pico's Adventure, video coding allowed us to determine the implications of using a physical setting that requires the users to be facing always to the front (Chapter 4). Moreover, we suggest the posterior correlation analysis between observed social acts from video coding, with the system data. Doing so, designers will be able to better correlate the experience design to the actual social behaviors outcome, as we did for Lands of Fog project (Chapter 5).

Pilot trials

Albeit being a standard methodology in research, we would like to formalize as a guideline the benefits of running pilot trials as a way of testing our designs before they are deployed. Although our experience as interaction designers might give us an intuition on how to develop systems for a specific goal, we suggest that designers always test the final design before starting evaluation in order to put under stress design, software and evaluation tools and methodologies.

Chapter 7

Conclusions

In this thesis, we have focused on the design, development and evaluation of three different full-body interaction systems for children with ASD, to later compile a series of guidelines for future research. The three different projects provide insight on the use of this kind of media for the development of intervention tools, which try to foster user's engagement and social behaviors. We present this thesis as an initial step towards assessing the potentialities of full-body interaction technologies for the development of such systems.

In the previous chapter (Chapter 6), we have presented a series of guidelines for designing and evaluating full-body interaction experiences for children with ASD geared at promoting engagement and social initiation. Although there has been research for more than a decade on full-body interaction for children with ASD (Section 2.4), no formal analysis of the potentialities of this media for designing experiences exist, for children with ASD aimed at promoting engagement and encouraging social initiation behaviors. With these guidelines, we want to contribute in the HCI research field of designing full-body interaction experiences as tools to aid intervention in motivation and social initiation for children with ASD.

We presented the MT installation SIIMTA for children with LFASD. The system provided insight on how to use full-body interaction for developing a system that would promote engagement in users and foster exploration, which is understood as the diversification of the activity during play. Given the high correlation between ASD and impairments in motor skills (MacDonald et al. 2014), developing systems which foster activity and control of virtual content might be a good approach to scaffold motor skills practicing. Although no significant results were found, we saw how the design of a first-person system helped children to quickly grasp the experience and make the interaction easy to understand (Chapter 3). Thus, having a full-body interaction experience based on music therapy, which children readily accepted, is a way of offering a structured scenario upon which children with ASD can easily improvise. This is an approach suggested by Grocke and Wigram (Grocke and Wigram 2006).

We presented Pico's Adventure, part of the M4ALL European project; a full-body interaction system for promoting social initiation behaviors in young children with HFASD. The system allowed us to see the potential risks a third-person paradigm could bring when designing interactive systems, imposed by the use of the Microsoft Kinect sensor. Nonetheless, we saw how this physical interface approach allows us to design and develop interactive experiences, where more specific social skills are put into practice. Moreover, we have seen through data analysis that the system was in general more effective than free play condition in eliciting social initiation behaviors. The findings are similar to those of the project by Bhattacharya et al. (Bhattacharya et al. 2015), where they also found positive results in social initiation through the use of a Microsoft Kinect sensor. We have seen that the use of PD for the design of interaction and content helped on developing a system easily accepted by the target population, as recommended by Frauenberger et al. (Frauenberger et al. 2012). Finally, orchestrating all scenarios around a defined narrative can help to better divide the different objectives of the system (Chapter 4).

The last system we presented, Lands of Fog, is a multi-user full-body interaction system based on a large floor projection for encouraging social and collaboration behaviors. The design and evaluation of the system allow us to validate the advantages of designing systems where users are collocated for the promotion and practice of social behaviors. Moreover, we have seen how the use of cultural forms (Horn 2013), combined with simple initial mechanics (Davis et al. 2010), is a good way of grasping users engagement. By using the peepholes technique (Dalsgaard and Dindler 2014), we have seen how we can motivate users exploration, translating also in engagement. While designing this system we also conducted PD sessions, and we have again observed that this design method helps on developing systems that are attractive for the objective population. Finally, the system helped us on understanding that it might not be necessary to enforce collaboration. By devising a gameplay around an open-ended experience, where narratives emerge from exploration, we have seen that gradually expanding the interaction capacities can naturally encourage collaboration (Chapter 5).

7.1 Limitations and Future Work

Although we have come up with a series of guidelines based on our findings, there are still points that need future exploration through a more fine grain evaluation of specific characteristics or approaches to full-body interaction:

Vertical vs horizontal

Two of the three projects we have presented were based on a vertical display configuration. From these two, only one of them, Pico's Adventure (Chapter 4), was a system specifically designed towards fostering social initiation behaviors in children with ASD. Through the video coding we observed that most of the social initiations were non-integrated, i.e. gaze was not integrated in the social initiation act. In most of the social acts users were looking directly to the screen (Section 4.5). From our experience with this system, we thought that it could be interesting other display orientations, as wee did with the floor projection from Lands of Fog (Chapter 5). Nonetheless, we did not see any significant improvements on integrated social behaviors in Lands on Fog.

We suggest that this is an important line of research for understanding the potentialities of full-body interaction for the development of systems which encourage social behaviors. In future work, we would like to develop similar interactive systems with two different physical display approaches. Thus, we could compare both a system with a vertical configuration and a system with an horizontal display configuration. Furthermore, in the future we would also like to do develop an interactive system where users could be wearing an active display device on their head which would be displaying necessary information for playing. A mixed interface design, such as the one we propose, could enforce users to look at each other when having to collaborate.

Narrative structure

From our experience, we can not draw a specific conclusion on which narrative (or a lack of it) approach to take when designing full-body interaction systems for promoting socialization in children with ASD. In Pico's Adventure (Chapter 4) we used a narrative based design while planning therapeutic sessions and game scenarios. Having a deep guided narrative experience was really useful for both the design process and for having a well defined progression learning curve during the experience. In contrast, for Lands of Fog we though for a background story of the virtual environment we designed, but there is no specific narrative evolution in the game. Some simpler, initial interaction mechanics are necessary to be deployed first, in order to unfold new and more complex ones, but in Lands of Fog there is not a specific narrative in the actions, nor a specific goal in the game. The experience is an open-ended game, where narratives emerge from users exploration and sharing of ideas. Lastly, SIIMTA was just an explorative installation with a complete abstract design. The visual content was just a mean to give visual feedback to user's activity and explore the sound space. Sounds were defined given a dataset from music therapists from "El Carrilet" and Tekhnikós Foundation.

Both Lands of Fog and Pico's Adventure were successful as scaffolds and promoters of social behaviors. Nonetheless, we can not suggest a specific guideline on how to approach the narrative design. We suggest that future research could focus on understanding which is the impact of having a virtual experience with a known and specific goal versus an open-ended experience. While having a well-defined goal seems to help children to take on the task and cooperate faster, having an experience where the goal is unknown seems to foster more social acts for guessing what is happening and for negotiating a common knowledge of the environment between the users.

Physical interactions

When designing Pico's Adventure we thought that one of the mechanics could be having both users holding hands to catch some falling objects. We adopted this approach as we thought that the shape of the two arms would have the cultural form of a basket, enforcing the notion of object collection. What we did not expect was that this would cause to users to stop verbal social initiations and just adopt instrumental behaviors, i.e. the physical use of somebody else for their own goals. Children with ASD no longer needed to communicate to achieve their goals as they could just push or pull their partner through the physical link. We suggest that future research focuses on understanding whether having a physical contact can really hinder social behaviors or whether it is a problem that derives from the gameplay, specifically related to the physical action. We suggest that new research is conducted by developing similar scenarios were a task can be achieved both through physical contact and through the use of an external object or without any contact. We believe that the necessity of cooperating and synchronizing activity without a physical link would foster more social acts than when the physical link is present.

Appendix **A**

Appendix

A.1 Questionnaire Used for SIIMTA Experimental Assessment

ALUMNE:
Data naixement:

VALORACIÓ DE LES SESSIONS

1 ª SESSIÓ **Data:** ___________________

Motivació prèvia:

Nul·la	1	2	3	4	5	Màxima

Comentaris:

Demandes o mostres a l'adult (a quin adult):

Cap	1	2	3	4	5	Moltes

Comentaris:

Com interacciona amb l'aplicatiu:

Gens	1	2	3	4	5	Molt

Comentaris:

Modificació/ variació de les accions respecte l'última sessió:

Gens	1	2	3	4	5	Molta

Comentaris:

Incorpora /imita alguna acció observada en els companys anteriors:

Gens	1	2	3	4	5	Molt

Comentaris:

Preferència per algunes columnes/files de sons *(amb intenció)*:

Altres aspectes a destacar:

Dades quantitatives

A.2 Video Coding Scheme for Pico's Adventure Assessment

CRITERIA	CATEGORY	DESCRIPTION
SOCIAL INITIATION	Integrated request	Social interaction **with eye contact** with the interlocutor aimed at **requesting something to the other,** such as asking the other to perform an action or asking for help or information about something. / E.g., *"Go to the right" "Do this," "Help" "How does this work?" "What is this?"*
	Non integrated request	Social interaction **without eye contact** with the interlocutor aimed at **requesting something to the other,** such as asking the other to perform an action or asking for help or information about something.
	Integrated Social commentaries	Social interaction **with eye contact** with the interlocutor aimed at **drawing the attention to something or sharing experience or making a social commentary. /** *E.g. "Oh! A pineapple!". "Look at this!" "Wow"*
	Non integrated Social commentaries	Social interaction **without eye contact** with the interlocutor aimed at **drawing the attention to something or sharing experience or making a social commentary**
OTHER SOCIAL INTERACTION	Non identified social interaction	Social interaction without comprehensible language
	Instrumentatio n	Using someone else in an instrumental manner./ E.g. Take his/her hand to make him/her do something
RESPONSES	Contextualized response	**Verbal and nonverbal responses** to social initiation made by the other that are **suitable and adequate** for the purpose of the communication. / E.g. giving an appropriate verbal answer; accomplish a requested action
	Non Contextualized response	**Verbal and nonverbal responses** to social initiation made by the other that are **not suitable and adequate** for the purpose of the communication / E.g. interrupt the other. shouting, doing something different, saying something unrelated
	No response	Failure to respond to questions or requests made by the other
INTERLOCUTOR	Game's character	Social initiations, requests or responses are addressed to an **element of the virtual environment.**
	Adult	Social initiations, requests or responses are addressed to the **accompanying adult.**
	Therapist	Social initiations, requests or responses are addressed to the **therapist.**
	Child	Social initiations, requests or responses are addressed to the other **child**.

SPONTANEOUS GESTURES	Conventional and Descriptive	Gesture with an explicit and acknowledged culturally established meaning (e.g. clapping)
	Emotional	Expressive gestures aimed toward expressing and communicating feelings
	Pointing	Point gesture to indicate something
	Greet	Greeting gesture
HELPS	Verbal	The therapist or the adult gives a verbal help to the child
	Modeling	The therapist or the adult gives a modeling help to the child
	Physical	The therapist or the adult gives a physical help to the child

A.3 Lands of Fog Barcelona Questionnaires

Qüestionari inicial

Nom del nen:	Data:
Persona que respon:	

1) Amb quina freqüència juga el teu fill amb videojocs?

1	2	3	4
Mai	Mensualment	Setmanalment	A diari

1a) En cas afirmatiu, en quines consoles?

- o Wii
- o Wii U
- o Xbox 360
- o Xbox 1
- o PC
- o Playstation 3
- o Playstation 4
- o Nintendo DS
- o Nintendo 3DS
- o PSP
- o PS Vita

1b) En cas afirmatiu, a quins jocs?

____
____
____
____

2) Utilitza el teu fill xarxes socials? Si / No

2b) En cas afirmatiu, quines xarxes socials?

____
____
____

3) Té el teu fill còmics, llibres, joguines i/o videojocs on hi apareguin criatures fantàstiques (com dracs, mags, fades, nans, etc...) ? Si / No

Primera sessió; Qüestionari pels pares

Nom del nen:	Data:
Persona que respon:	

1) Com valores l'actitud inicial del teu fill cap al videojoc?

1	2	3	4	5
Molt negativa				Molt positiva

2) Com valores l'actitud del teu fill cap al videojoc al finalitzar la sessió?

1	2	3	4	5
Molt negativa				Molt positiva

3) Abans de la sessió, quina creies que seria l'actitud del teu fill cap al videojoc?

1	2	3	4	5
Molt negativa				Molt positiva

4) Creus que el teu fill s'ha mostrat participatiu amb el videojoc?

1	2	3	4	5
Gens				Tota l'estona

5) Abans de la sessió, creies que es mostraria participatiu amb el videojoc?

1	2	3	4	5
Gens				Tota l'estona

6a) Durant la sessió, el teu fill s'ha comunicat de forma no verbal amb tu? Si / No

6b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1	2	3	4	5	6	7
	← Menys de l'habitual		Com sempre		Més de l'habitual →	

7a) Ha respòs el teu fill a les demandes no-verbals del company durant la sessió? Si / No

7b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

8a) Durant la sessió, ha començat el teu fill a parlar amb el company? Si / No

8b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

9a) Durant la sessió, quan el company ha parlat al teu fill, ha respòs? Si / No

9b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

10) Quant flexible creus que ha estat el comportament del teu fill durant la sessió (s'ha adaptat als canvis, diferents situacions, etc...)?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

11) S'ha mostrat actiu durant la sessió?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

Segona sessió; Qüestionari pels pares

Nom del nen:	Data:
Persona que respon:	

1) Comparant-ho amb altres activitats, quant creus que ha parlat sobre el videojoc el teu fill?

1 2 3 4 5 6 7

Igual

← Menys de l'habitual | Més de l'habitual →

2) Ha expressat alguna opinió sobre el videojoc? Si / No

2b) En cas afirmatiu, aquesta ha estat:

1 2 3 4 5

Molt negativa Molt positiva

3a) Ha expressat alguna opinió sobre l'experiència de jugar amb un company? Si / No

3b) En cas afirmatiu, aquesta ha estat:

1 2 3 4 5

Molt negativa Molt positiva

4) Com valores l'actitud inicial del teu nen cap al videojoc al principi de la segona sessió?

1 2 3 4 5

Molt negativa Molt positiva

5) Com valores l'actitud del teu nen cap al videojoc al finalitzar la segona sessió?

1 2 3 4 5

Molt negativa Molt positiva

6) Abans de la segona sessió, quina creies que seria l'actitud del teu fill cap al videojoc?

1 2 3 4 5

Molt negativa Molt positiva

7) Creus que el teu fill s'ha mostrat participatiu amb el videojoc?

1 2 3 4 5

Gens Tota l'estona

8) Abans de la sessió, creies que es mostraria participatiu amb el videojoc?

1	2	3	4	5
Gens				Tota l'estona

9a) Durant la sessió, el teu fill s'ha comunicat de forma no verbal amb tu? Si / No

9b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual — Més de l'habitual

10a) Ha respòs el teu fill a les demandes no verbals del company durant la sessió? Si / No

10b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual — Més de l'habitual

11a) Durant la sessió, ha començat el teu fill a parlar amb el company? Si / No

11b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual — Més de l'habitual

12a) Durant la sessió, quan el company ha parlat al teu fill, ha respòs? Si / No

12b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual — Més de l'habitual

13) Quant flexible creus que ha estat el comportament del teu fill durant la sessió (s'ha adaptat als canvis, diferents situacions, etc...)?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

14) S'ha mostrat actiu durant la sessió?

1	2	3	4	5	6	7
			Com sempre			
	Menys de l'habitual				Més de l'habitual	

Tercera sessió;   Qüestionari pels pares

Nom del nen:	Data:
Persona que respon:	

1) Comparant-ho amb altres activitats, quant creus que ha parlat sobre el videojoc el teu fill?

1	2	3	4	5	6	7
← Menys de l'habitual			Igual			Més de l'habitual →

2) Ha expressat alguna opinió sobre el videojoc?   Si / No

2b) En cas afirmatiu, aquesta ha estat:

1	2	3	4	5
Molt negativa				Molt positiva

3) Ha expressat alguna opinió sobre l'experiència de jugar amb un company?   Si / No

3b) En cas afirmatiu, aquesta ha estat:

1	2	3	4	5
Molt negativa				Molt positiva

4) Com valores l'actitud inicial del teu nen cap al videojoc al principi de la tercera sessió?

1	2	3	4	5
Molt negativa				Molt positiva

5) Com valores l'actitud del teu nen cap al videojoc al finalitzar la tercera sessió?

1	2	3	4	5
Molt negativa				Molt positiva

6) Abans de la tercera sessió, quina creies que seria l'actitud del teu fill cap al videojoc?

1	2	3	4	5
Molt negativa				Molt positiva

7) Creus que el teu fill s'ha mostrat participatiu amb el videojoc?

1	2	3	4	5
Gens				Tota l'estona

8) Abans de la sessió, creies que es mostraria participatiu amb el videojoc?

1	2	3	4	5
Gens				Tota l'estona

9a) Durant la sessió, el teu fill s'ha comunicat de forma no verbal amb tu? Si / No

9b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual ← → Més de l'habitual

10a) Ha respòs el teu fill a les demandes no verbals del company durant la sessió? Si / No

10b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual ← → Més de l'habitual

11a) Durant la sessió, ha començat el teu fill a parlar amb el company? Si / No

11b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual ← → Més de l'habitual

12a) Durant la sessió, quan el company ha parlat al teu fill, ha respòs? Si / No

12b) En cas afirmatiu. Si ho compareu amb les situacions social quotidianes, en quina freqüència creieu que s'han donat durant el videojoc?

1 2 3 4 5 6 7

Com sempre

Menys de l'habitual ← → Més de l'habitual

13) Quant flexible creus que ha estat el comportament del teu fill durant la sessió (s'ha adaptat als canvis, diferents situacions, etc...)?

1	2	3	4	5	6	7
←	Menys de l'habitual		Com sempre		Més de l'habitual	→

14) S'ha mostrat actiu durant la sessió?

1	2	3	4	5	6	7
←	Menys de l'habitual		Com sempre		Més de l'habitual	→

Valoració final; Qüestionari pels pares

Nom del nen:	Data:
Persona que respon:	

1) Ha canviat l'actitud del vostre fill cap al videojoc a mesura que han avançat les sessions?

1	2	3	4	5
Més negativa		No ha canviat		Més positiva

2) Creus que l'actitud del teu nen a jugar amb un altre nen ha canviat a mesura que han avançat les sessions?

1	2	3	4	5
Més negativa		No ha canviat		Més positiva

3) Creus que hi ha hagut algun canvi en el teu fill a l'hora de començar a parlar amb els companys del videojoc des del principi de les sessions?

1	2	3	4	5
Menys de l'habitual		Com sempre		Més de l'habitual

4) Creus que hi ha hagut algun canvi en el teu fill a l'hora de respondre a els companys del videojoc des del principi de les sessions?

1	2	3	4	5
Menys de l'habitual		Com sempre		Més de l'habitual

5) Creus que el grau de rigidesa del teu fill ha canviat des del inici de les sessions?

1	2	3	4	5
Més rígid		Com sempre		Més flexible

6) Creus que el nivell d'activitat del teu fill ha canviat des del inici de les sessions?

1	2	3	4	5
Menys actiu		Com sempre		Més actiu

7) Altres comentaris:

A.4 Lands of Fog London Questionnaires

Name…………………………………………………………………………………………………….

Age……………………………….

Male/Female (please circle)

ASD/TD

Pre-session

The children will be asked the following questions by Jean

- How often do you play video games?
  Daily / 6 days a week / 2-3 days a week / Once a week / Monthly / Never

- Do you play online video games?
  Daily / 6 days a week / 2-3 days a week / Once a week / Monthly / Never

- How often do you use social media?

  Very Often Often Occasionally Not often Never

- Are you interested in mythical creatures?

  Very interested A bit interested Neutral Not very interested Not at all interested

Then Jean will talk to the child about not sharing his/her experience of playing the game with other children in the school

End of session questions to be completed by Jean

- How flexible (adapting to changes, different situations etc) was the child during the session?

(please circle below)

Less than than usual	1	2	3	4	5	6	7	More usual

- How active was the child during the session?

(please circle below)

Less than than usual	1	2	3	4	5	6	7	More usual

Child Interview

1) Did you find you got more into the game as time went on? Yes/no

If YES, where you (a) a bit more into it (b) a lot more into it (c) massively more into it

If NO, where you (a) a bit less into it (b) a lot less into it (c) massively less into it.

2) Did you think it was easy or hard to get your partner to play with you at the beginning?

If easy, was it (a) a bit easier (b) a lot easier (c) massively easier

If hard, was it (a) a bit harder (b) a lot harder c) massively harder

3) Did you find that it got easier <u>OR</u> harder to get your partner to play with you as time went on?

If easier, was it (a) a bit easier (b) a lot easier (c) massively easier

If harder, was it (a) a bit harder (b) a lot harder c) massively harder

4) Was it easier <u>OR</u> harder to get your partner to play with you in the game than it would have been outside? Like in the playground or somewhere out of school.

If easier, was it (a) a bit easier (b) a lot easier (c) massively easier

If harder, was it (a) a bit harder (b) a lot harder c) massively harder

5) Did your partner try to get you to play with him/her? For example did s/he call out and ask you to play? Or did s/he show you objects or ask you to put your creatures together.

If yes, was it (a) a bit (b) a lot (c) masses

6) Did you like it when your partner tried to get you to play

If yes, did you like it (a) a bit (b) a lot (c) really really liked it

7) How much did you enjoy catching insects on your own?

(a) a bit (b) a lot (c) really really liked it

8) How much did you enjoy catching insects with your partner?

(a) a bit (b) a lot (c) really really liked it

9) How much did you enjoy creating creatures on your own?

(a) a bit (b) a lot (c) really really liked it

10) How much did you enjoy creating creatures with your partner?

(a) a bit (b) a lot (c) really really liked it

11) How much did you like it when the creatures merged (score as above)

If yes, did you like it (a) a bit (b) a lot (c) really really liked it

If no, did you dislike it (a) a bit (b) a lot (c) really really disliked it

12) Did you find that you talked to you partner more <u>OR</u> less as the game went on?

If more, was it (a) a bit more (b) a lot more (c) masses more

If less, was it (a) a bit less (b) a lot less c) masses less

13) Did you find that your partner talked to you more <u>OR</u> less as the game went on?

If more, was it (a) a bit more (b) a lot more (c) masses more

If less, was it (a) a bit less (b) a lot less c) masses less

14) If you were in the playground at school, do you think you would have talked to your partner more <u>OR</u> less than you did when you were playing the game?

If more, was it (a) a bit more (b) a lot more (c) masses more

If less, was it (a) a bit less (b) a lot less c) masses less

15) Did you enjoy working with your partner in the game more than you would have enjoyed working with him/her in PE?

If yes, was this (a) a bit more (b) a lot more (c) massively more

If no, was it (a) a bit less (b) a lot less (c) massively less

16) Did you enjoy working with your partner in the game more than you would have enjoyed working with him/her on a science practical?

If yes, was this (a) a bit more (b) a lot more (c) massively more

If no, was it (a) a bit less (b) a lot less (c) massively less

17) Did you enjoy working with your partner in the game more than you would have enjoyed working with him/her in drama?

If yes, was this (a) a bit more (b) a lot more (c) massively more

If no, was it (a) a bit less (b) a lot less (c) massively less

18) How well did you know your partner before you played together in the game?

(a) Very well (b) fairly well (c) not very well (d) not at all

19) Do you think you would like to get to know you partner better now?

If yes. Use LIKERT SCALE SLIDE

20) Would you like to come back to play this game?

If yes, did you like it (a) a bit (b) a lot (c) really really would play again

If no, did you dislke it (a) a bit (b) a lot (c) really really would not play again

21) What do you think the game is about?

Post-test. If it is possible to organise, I would like to bring the children together so that they can ask the Barcelona team questions about how they developed the game. We could ask the children for comments on their experience of playing the game.

Bibliography

Each reference indicates the pages where it appears.

E. K. Ackermann. Constructing Knowledge and Transforming the World. *A learning zone of one's own: Sharing representations and flow in collaborative learning environments*, pages 15–37, 2004. 24

R. Agarwal, H. Sampath, and B. Indurkhya. AUTINECT - Helping children with autism acquire social skills through virtual peers. In *1st International Conference on Innovative Technologies for Autism Spectrum Disorders*, Valencia, 2012. 35, 75

A. Alcorn, H. Pain, G. Rajendran, T. Smith, O. Lemon, K. Porayska-Pomsta, M. E. Foster, K. Avramides, C. Frauenberger, and S. Bernardini. Social communication between virtual characters and children with autism. *Lecture Notes in Computer Science*, 6738:7–14, jun 2011a. 33

A. Alcorn, H. Pain, G. Rajendran, T. Smith, O. Lemon, K. Porayska-Pomsta, M. E. Foster, K. Avramides, C. Frauenberger, and S. Bernardini. *Artificial Intelligence in Education*, volume 6738 of *Lecture Notes in Computer Science*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2011b. ISBN 978-3-642-21868-2. doi: 10.1007/978-3-642-21869-9. 28

A. M. Alcorn, H. Pain, and J. Good. Discrepancies in a virtual learning environment. In *Proceedings of the 12th International Confer-*

ence on Interaction Design and Children - IDC '13, pages 56–65, New York, New York, USA, 2013. ACM Press. ISBN 9781450319188. doi: 10.1145/2485760.2485783. 15

A. M. Alcorn, H. Pain, and J. Good. Motivating children's initiations with novelty and surprise. In *Proceedings of the 2014 conference on Interaction design and children - IDC '14*, pages 225–228, New York, New York, USA, jun 2014. ACM Press. 109, 155, 169

A. Anderson, J. Locke, M. Kretzmann, C. Kasari, and AIR-B Network. Social network analysis of children with autism spectrum disorder: Predictors of fragmentation and connectivity in elementary school classrooms. *Autism*, 2015. ISSN 1362-3613. doi: 10.1177/1362361315603568. 17, 145

A. N. Antle. Research opportunities: Embodied child-computer interaction. *International Journal of Child-Computer Interaction*, 1(1):30–36, jan 2013. ISSN 22128689. 26

A. N. Antle, G. Corness, and M. Droumeva. What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments. *Interacting with Computers*, 21(1-2):66–75, jan 2009. ISSN 09535438. doi: 10.1016/j.intcom.2008.10.005. 2

A. P. Association. Cautionary Statement for Forensic Use of DSM-5. In A. P. Association, editor, *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition*. American Psychiatric Publishing, Inc, Washington, DC, 5 edition, 2013. doi: 10.1176/appi.books.9780890425596.744053. 2, 14, 15, 16, 18

S. Baron-Cohen. *Autism and Asperger Syndrome*. Oxford University Press, 2008. ISBN 9780198504900. 18

S. Baron-Cohen. Autism: the empathizing-systemizing (E-S) theory. *Annals of the New York Academy of Sciences*, 1156:68–80, mar 2009. ISSN 1749-6632. 15

L. Bartoli, C. Corradi, F. Garzotto, and M. Valoriani. Exploring motion-based touchless games for autistic children's learning. In *Proceedings of the 12th International Conference on Interaction Design and Children - IDC '13*, pages 102–111, New York, New York, USA, jun 2013. ACM

Press. ISBN 9781450319188. doi: 10.1145/2485760.2485774. 26

L. Bartoli, F. Garzotto, M. Gelsomini, L. Oliveto, and M. Valoriani. Designing and evaluating touchless playful interaction for ASD children. In *Proceedings of the 2014 conference on Interaction design and children - IDC '14*, pages 17–26, New York, New York, USA, 2014. ACM Press. ISBN 9781450322720. doi: 10.1145/2593968.2593976. 155

N. Bauminger, M. Solomon, and S. J. Rogers. Externalizing and internalizing behaviors in ASD. *Autism research : official journal of the International Society for Autism Research*, 3(3):101–12, jun 2010. ISSN 1939-3806. doi: 10.1002/aur.131. 17, 31

N. Bauminger-Zviely, S. Eden, M. Zancanaro, P. L. Weiss, and E. Gal. Increasing social engagement in children with high-functioning autism spectrum disorder using collaborative technologies in the school environment. *Autism : the international journal of research and practice*, 17(3): 317–39, may 2013. ISSN 1461-7005. 34

N. Bauminger-Zviely, E. Karin, Y. Kimhi, and G. Agam-Ben-Artzi. Spontaneous peer conversation in preschoolers with high-functioning autism spectrum disorder versus typical development. *Journal of Child Psychology and Psychiatry*, 55(4):363–373, apr 2014. ISSN 00219630. doi: 10.1111/jcpp.12158. 17, 72

A. Ben-Sasson, L. Lamash, and E. Gal. To enforce or not to enforce? The use of collaborative interfaces to promote social skills in children with high functioning autism spectrum disorder. *Autism*, 17(5):608–622, sep 2013. ISSN 1362-3613. doi: 10.1177/1362361312451526. 20, 31, 159, 170

D. S. Berger. *Music Therapy, Sensory Integration and the Autistic Child*. Jessica Kingsley Publishers, 2002. ISBN 978-1-84310-700-2. 20

A. Bhattacharya, M. Gelsomini, P. Pérez-Fuster, G. D. Abowd, and A. Rozga. Designing motion-based activities to engage students with autism in classroom settings. In *Proceedings of the 14th International Conference on Interaction Design and Children - IDC '15*, pages 69–78, New York, New York, USA, jun 2015. ACM Press. ISBN 9781450335904. doi: 10.1145/2771839.2771847. 36, 174

N. Bianchi-Berthouze, W. W. Kim, and D. Patel. Does Body Movement Engage You More in Digital Game Play? and Why? In *Affective Computing and Intelligent Interaction*, pages 102–113. Springer Berlin Heidelberg, Berlin, Heidelberg, 2007. doi: 10.1007/978-3-540-74889-2{_}10. 2, 4

V. Bolic Baric, K. Hellberg, A. Kjellberg, and H. Hemmingsson. Support for learning goes beyond academic support: Voices of students with Asperger's disorder and attention deficit hyperactivity disorder. *Autism : the international journal of research and practice*, 20(2):183–95, feb 2016. ISSN 1461-7005. 17

A. Bonnel, L. Mottron, I. Peretz, M. Trudel, E. Gallun, and A.-M. Bonnel. Enhanced pitch sensitivity in individuals with autism: a signal detection analysis. *Journal of cognitive neuroscience*, 15(2):226–35, feb 2003. ISSN 0898-929X. 21

A. M. Borghi and F. Cimatti. Embodied cognition and beyond: acting and sensing the body. *Neuropsychologia*, 48(3):763–73, mar 2010. ISSN 1873-3514. doi: 10.1016/j.neuropsychologia.2009.10.029. 1

A. Bosseler and D. W. Massaro. Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of autism and developmental disorders*, 33(6):653–72, dec 2003. ISSN 0162-3257. 29

K. Bottema-Beutel, T. S. Mullins, M. N. Harvey, J. R. Gustafson, and E. W. Carter. Avoiding the "brick wall of awkward": Perspectives of youth with autism spectrum disorder on social-focused intervention practices. *Autism : the international journal of research and practice*, pages 1362361315574888–, apr 2015. ISSN 1461-7005. doi: 10.1177/1362361315574888. 17, 170

B. A. Boyd, K. Hume, M. T. McBee, M. Alessandri, A. Gutierrez, L. Johnson, L. Sperry, and S. L. Odom. Comparative efficacy of LEAP, TEACCH and non-model-specific special education programs for preschoolers with autism spectrum disorders. *Journal of autism and developmental disorders*, 44(2):366–80, feb 2014. ISSN 1573-3432. 27

R. A. Brooks. Cambrian intelligence: the early history of the new AI. sep 1999. 24

J. Brown and D. Murray. Strategies For Enhancing Play Skills For Children With Autism Spectrum Disorder. *Education and Training in Mental Retardation and Developmental Disabilities*, 36(3):312–317, 2001. 27, 169

K. E. Bruscia. *Defining Music Therapy*. 1998. 20

W. Buxton. There's more to interaction than meets the eye: some issues in manual input. pages 122–137, may 1990. 25

R. Caillois and M. Barash. *Man, Play, and Games*. University of Illinois Press, 1961. 19

J. H. Carlisle. Evaluating the impact of office automation on top management communication. In *Proceedings of the June 7-10, 1976, national computer conference and exposition on - AFIPS '76*, page 611, New York, New York, USA, jun 1976. ACM Press. doi: 10.1145/1499799.1499885. 1

E. G. Carr. The motivation of self-injurious behavior: a review of some hypotheses. *Psychological bulletin*, 84(4):800–16, jul 1977. ISSN 0033-2909. 18

E. G. Carr, G. Dunlap, R. H. Horner, R. L. Koegel, A. P. Turnbull, W. Sailor, J. L. Anderson, R. W. Albin, L. K. Koegel, and L. Fox. Positive Behavior Support: Evolution of an Applied Science. *Journal of Positive Behavior Interventions*, 4(1):4–16, jan 2002. ISSN 1098-3007. 22

X. Casas, G. Herrera, I. Coma, and M. Fernandez. A Kinect-Based Augmented Reality System for Individuals with Autism Spectrum Disorders. *GRAPP/IVAPP*, pages 440–446, 2012. doi: 978-989-8565-02-0. 34, 35, 143

D. M. Casenhiser, S. G. Shanker, and J. Stieben. Learning through interaction in children with autism: preliminary data from asocial-communication-based intervention. *Autism : the international journal of research and practice*, 17(2):220–41, mar 2013. ISSN 1461-7005. doi: 10.1177/1362361311422052. 19

K. R. Cebula. Applied behavior analysis programs for autism: sibling psychosocial adjustment during and following intervention use. *Journal of autism and developmental disorders*, 42(5):847–62, may 2012. ISSN 1573-3432. 21, 70

D. R. Cerbone. *Understanding phenomenology.* 2006. 24

B. Charlton, R. L. Williams, and T. F. McLaughlin. Educational Games: A Technique to Accelerate the Acquisition of Reading Skills of Children with Learning Disabilities. *International Journal of Special Education*, 20(2):66–72, nov 2004. ISSN ISSN-0827-3383. 27

Y. Cheng and J. Ye. Exploring the social competence of students with autism spectrum conditions in a collaborative virtual learning environment - The pilot study. *Computers & Education*, 54(4):1068–1077, may 2010. ISSN 03601315. doi: 10.1016/j.compedu.2009.10.011. 30, 143

D. L. Christensen, D. A. Bilder, W. Zahorodny, S. Pettygrove, M. S. Durkin, R. T. Fitzgerald, C. Rice, M. Kurzius-Spencer, J. Baio, and M. Yeargin-Allsopp. Prevalence and Characteristics of Autism Spectrum Disorder Among 4-Year-Old Children in the Autism and Developmental Disabilities Monitoring Network. *Journal of developmental and behavioral pediatrics : JDBP*, 37(1):1–8, jan 2016. ISSN 1536-7312. 14, 51

S. Cobb, S. Parsons, L. Millen, R. Eastgate, and T. Glover. Design and Development of Collaborative Technology for Children with Autism: COSPATIAL, mar 2010. ISSN 2340-1079. 34

M. B. Coleman-Martin, K. W. Heller, D. F. Cihak, and K. L. Irvine. Using Computer-Assisted Instruction and the Nonverbal Reading Approach to Teach Word Identification. *Focus on Autism and Other Developmental Disabilities*, 20(2):80–90, jan 2005. ISSN 1088-3576. doi: 10.1177/10883576050200020401. 30

C. M. Corsello. Early Intervention in Autism. *Infants & Young Children*, 18(2):74–85, apr 2005. ISSN 0896-3746. 18

P. Dalsgaard and C. Dindler. Between theory and practice. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, pages 1635–1644, New York, New York, USA, apr 2014. ACM Press. ISBN 9781450324731. doi: 10.1145/2556288.2557342. 84, 110, 118, 155, 159, 169, 175

K. Dautenhahn, B. Ogden, and T. Quick. From embodied to socially embedded agents - Implications for interaction-aware robots. *Cognitive Systems Research*, 3(3):397–428, sep 2002. ISSN 13890417. 31

M. Davis, K. Dautenhahn, S. D. Powell, and C. L. Nehaniv. Guidelines for researchers and practitioners designing software and software trials for children with autism. *Journal of Assistive Technologies*, 4(1):38–48, 2010. doi: 10.5042/jat.2010.0043. 28, 108, 109, 121, 143, 154, 158, 169, 175

W. B. Davis, K. E. Gfeller, and M. H. Thaut. *An Introduction to Music Therapy: Theory and Practice*. 1999. 44

G. Dawson, E. J. H. Jones, K. Merkle, K. Venema, R. Lowy, S. Faja, D. Kamara, M. Murias, J. Greenson, J. Winter, M. Smith, S. J. Rogers, and S. J. Webb. Early behavioral intervention is associated with normalized brain activity in young children with autism. *Journal of the American Academy of Child and Adolescent Psychiatry*, 51(11):1150–9, nov 2012. ISSN 1527-5418. 21, 22, 70, 75

H. De Jaegher. Embodiment and sense-making in autism. *Frontiers in integrative neuroscience*, 7:15, jan 2013. ISSN 1662-5145. doi: 10.3389/fnint.2013.00015. 17, 25, 158, 159, 170

S. Deterding, D. Dixon, R. Khaled, and L. Nacke. From game design elements to gamefulness. In *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '11*, page 9, New York, New York, USA, sep 2011. ACM Press. 27

E. A. Di Paolo, M. Rohde, and H. De Jaegher. Horizons for the Enactive Mind: Values, Social Interaction, and Play. In *Enaction*, pages 32–87. The MIT Press, nov 2010. doi: 10.7551/mitpress/9780262014601.003.0003. 25

P. Dillenbourg and M. Evans. Interactive tabletops in education. *International Journal of Computer-Supported Collaborative Learning*, 6(4):491–514, aug 2011. ISSN 1556-1607. 26

P. Dourish. *Where the Action is: The Foundations of Embodied Interaction.* 2004. 26, 75

A. Duquette, F. Michaud, and H. Mercier. Exploring the use of a mobile robot as an imitation agent with children with low-functioning autism. *Autonomous Robots*, 24(2):147–157, oct 2007. ISSN 0929-5593. 31

T. T. Dyches, A. Davis, B. Lucido, and J. Young. Generalization of skills using pictographic and voice output communication devices. *Augmentative and Alternative Communication*, 18(2):124–131, jan 2002. ISSN 0743-4618. doi: 10.1080/07434610212331281211. 29

V. Eapen, R. Crnčec, and A. Walter. Clinical outcomes of an early intervention program for preschool children with Autism Spectrum Disorder in a community group setting. *BMC pediatrics*, 13(1):3, jan 2013. ISSN 1471-2431. 21

L. J. Eason, M. J. White, and C. Newsom. Generalized reduction of self-stimulatory behavior: An effect of teaching appropriate play to autistic children. *Analysis and Intervention in Developmental Disabilities*, 2(2-3):157–169, jan 1982. ISSN 02704684. doi: 10.1016/0270-4684(82)90016-7. 18

P. Ehn. Work-Oriented Design of Computer Artifacts. mar 1990. 77, 126

A. Estes, L. Vismara, C. Mercado, A. Fitzpatrick, L. Elder, J. Greenson, C. Lord, J. Munson, J. Winter, G. Young, G. Dawson, and S. Rogers. The impact of parent-delivered intervention on parents of very young children with autism. *Journal of autism and developmental disorders*, 44 (2):353–65, feb 2014. ISSN 1573-3432. 70

W. Farr, N. Yuill, and H. Raffle. Social benefits of a tangible user interface for children with Autistic Spectrum Conditions. *Autism : the international journal of research and practice*, 14(3):237–52, may 2010. ISSN 1461-7005. 32

P. A. Filipek, P. J. Accardo, S. Ashwal, G. T. Baranek, E. H. Cook, G. Dawson, B. Gordon, J. S. Gravel, C. P. Johnson, R. J. Kallen, S. E. Levy, N. J. Minshew, S. Ozonoff, B. M. Prizant, I. Rapin, S. J. Rogers, W. L. Stone, S. W. Teplin, R. F. Tuchman, and F. R. Volkmar. Practice parameter: Screening and diagnosis of autism: Report of the Quality Standards Subcommittee of the American Academy of Neurology and the Child Neurology Society. *Neurology*, 55(4):468–479, aug 2000. ISSN 0028-3878. 14

C. Frauenberger, J. Good, A. Alcorn, and H. Pain. Supporting the design contributions of children with autism spectrum conditions. In *Proceedings of the 11th International Conference on Interaction Design and Children*, pages 134–143, 2012. doi: 10.1145/2307096.2307112. 77, 164, 174

A. Frischen, A. P. Bayliss, and S. P. Tipper. Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, 133(4):694–724, 2007. ISSN 1939-1455. doi: 10.1037/0033-2909.133.4.694. 154, 157

U. Frith. Mind blindness and the brain in autism. *Neuron*, 32(6):969–79, dec 2001. ISSN 0896-6273. 15

T. Fuchs and H. De Jaegher. Enactive intersubjectivity: Participatory sense-making and mutual incorporation. *Phenomenology and the Cognitive Sciences*, 8(4):465–486, jul 2009. ISSN 1568-7759. 24

R. L. Gabriels, M. L. Cuccaro, D. E. Hill, B. J. Ivers, and E. Goldson. Repetitive behaviors in autism: relationships with associated clinical features. *Research in developmental disabilities*, 26(2):169–81, jan 2005. ISSN 0891-4222. 18, 58, 151

C. Gillberg and B. Kadesjö. Why bother about clumsiness? The implications of having developmental coordination disorder (DCD). *Neural plasticity*, 10(1-2):59–68, jan 2003. ISSN 2090-5904. 18

D. H. Goh, R. P. Ang, and H. C. Tan. Strategies for designing effective psychotherapeutic gaming interventions for children and adolescents. *Computers in Human Behavior*, 24(5):2217–2235, sep 2008. ISSN 07475632. doi: 10.1016/j.chb.2007.10.007. 27

O. Golan and S. Baron-Cohen. Systemizing empathy: teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. *Development and psychopathology*, 18 (2):591–617, jan 2006. ISSN 0954-5794. 30

S. Goldin-Meadow. Learning through gesture. *Wiley interdisciplinary reviews. Cognitive science*, 2(6), jan 2011. ISSN 1939-5086. 26

T. R. Goldsmith and L. A. LeBlanc. Use of Technology in Interventions for Children with Autism. *Journal of Early and Intensive Behavior Intervention*, 1(2):166–178, nov 2003. ISSN ISSN-1554-4893. 28

S. A. Grandhi, G. Joue, and I. Mittelberg. Understanding naturalness and intuitiveness in gesture production. In *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*, page 821, New York, New York, USA, may 2011. ACM Press. ISBN 9781450302289. doi: 10.1145/1978942.1979061. 27

C. A. Gray and J. D. Garand. Social Stories: Improving Responses of Students with Autism with Accurate Social Information. *Focus on Autism and Other Developmental Disabilities*, 8(1):1–10, apr 1993. ISSN 1088-3576. 33

J. Green, T. Charman, H. McConachie, C. Aldred, V. Slonims, P. Howlin, A. Le Couteur, K. Leadbitter, K. Hudry, S. Byford, B. Barrett, K. Temple, W. Macdonald, and A. Pickles. Parent-mediated communication-focused treatment in children with autism (PACT): a randomised controlled trial. *Lancet (London, England)*, 375(9732):2152–60, jun 2010. ISSN 1474-547X. 19

C. F. Grindle, R. P. Hastings, M. Saville, J. C. Hughes, K. Huxley, H. Kovshoff, G. M. Griffith, E. Walker-Jones, K. Devonshire, and B. Remington. Outcomes of a behavioral education model for children with autism in a mainstream school setting. *Behavior modification*, 36(3): 298–319, may 2012. ISSN 1552-4167. 21

D. Grocke and T. Wigram. *Receptive Methods in Music Therapy: Techniques and Clinical Applications for Music Therapy Clinicians, Educators and Students.* 2006. 20, 174

J. Grudin. The computer reaches out: the historical continuity of interface design. In *Proceedings of the SIGCHI conference on Human factors in computing systems Empowering people - CHI '90*, pages 261–268, New York, New York, USA, mar 1990. ACM Press. 25

O. Grynszpan, J.-C. Martin, and J. Nadel. Multimedia interfaces for users with high functioning autism: An empirical investigation. *International Journal of Human-Computer Studies*, 66(8):628–639, aug 2008. ISSN 10715819. doi: 10.1016/j.ijhcs.2008.04.001. 17

S. S. Gupta, M. E. Vinh, and W. R. H. IV. First Steps to Preschool Inclusion: How to Jumpstart Your Programwide Plan. 2014. 116

G. R. Hayes, S. Hirano, G. Marcu, M. Monibi, D. H. Nguyen, and M. Yeganyan. Interactive visual supports for children with autism. *Personal and Ubiquitous Computing*, 14(7):663–680, apr 2010. ISSN 1617-4909. doi: 10.1007/s00779-010-0294-8. 29, 30

P. F. Heaton, B. Hermelin, and L. Pring. Autism and pitch processing: a precursor for savant musical ability?, mar 1998. 21

H. Hendriks-Jansen. Catching Ourselves in the Act: Situated Activity, Interactive Emergence, Evolution, and Human Thought. jul 1996. 24

T. T. Hewett, R. Baecker, S. Card, T. Carey, J. Gasen, M. Mantei, G. Perlman, G. Strong, and W. Verplank. *ACM SIGCHI Curricula for Human-Computer Interaction*. ACM, New York, New York, USA, jan 1992. ISBN 0-89791-474-0. 1

P. Hoberman, N. Pares, and R. Pares. El ball del fanalet or lightpools. jan 1999. 114, 157

I. M. Hopkins, M. W. Gower, T. A. Perez, D. S. Smith, F. R. Amthor, F. C. Wimsatt, and F. J. Biasini. Avatar assistant: improving social skills in students with an ASD through a computer-based intervention. *Journal of autism and developmental disorders*, 41(11):1543–55, nov 2011. ISSN 1573-3432. 33, 75

M. E. Hoque, J. K. Lane, R. el Kaliouby, M. Goodwin, and R. W. Picard. Exploring Speech Therapy Games with Children on the Autism Spectrum. In *INTERSPEECH*, pages 1455–1458, 2009. 27

M. S. Horn. The role of cultural forms in tangible interaction design. *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, pages 117–124, 2013. doi: 10.1145/2460625.

2460643. 158, 169, 175

M. Howison, D. Trninic, D. Reinholz, and D. Abrahamson. The Mathematical Imagery Trainer: from embodied interaction to conceptual learning. In *Proceedings of the annual meeting of CHI: ACM Conference on Human Factors in Computing Systems (CHI 2011)*, pages 1989 – 1998. ACM, 2011. 2

C. Hughes. Brief report: Planning problems in autism at the level of motor control. *Journal of Autism and Developmental Disorders*, 26(1):99–107, feb 1996. ISSN 0162-3257. doi: 10.1007/BF02276237. 18

E. Husserl. *Cartesian Meditations*. Springer Netherlands, Dordrecht, 1977. ISBN 902470068X, 9789024700684. doi: 10.1007/978-94-009-9997-8. 23

B. Ingersoll. The Social Role of Imitation in Autism. *Infants & Young Children*, 21(2):107–119, apr 2008. ISSN 0896-3746. 31

C. P. Johnson and S. M. Myers. Identification and evaluation of children with autism spectrum disorders. *Pediatrics*, 120(5):1183–215, nov 2007. ISSN 1098-4275. 18, 58, 151

J. M. Johnston, R. M. Foxx, J. W. Jacobson, G. Green, and J. A. Mulick. Positive behavior support and applied behavior analysis. *The Behavior analyst / MABA*, 29(1):51–74, jan 2006. ISSN 0738-6729. 21, 70

D. H. Jonassen and L. Rohrer-Murphy. Activity theory as a framework for designing constructivist learning environments. *Educational Technology Research and Development*, 47(1):61–79, mar 1999. ISSN 1042-1629. doi: 10.1007/BF02299477. 115

C. Kasari, T. Paparella, S. Freeman, and L. B. Jahromi. Language outcome in autism: randomized comparison of joint attention and play interventions. *Journal of consulting and clinical psychology*, 76(1):125–37, feb 2008. ISSN 0022-006X. 17, 19, 105

C. Kasari, A. C. Gulsrud, C. Wong, S. Kwon, and J. Locke. Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *Journal of autism and developmental disorders*, 40(9):1045–56, sep 2010. ISSN 1573-3432. 22

C. Kasari, E. Rotheram-Fuller, J. Locke, and A. Gulsrud. Making the connection: randomized controlled trial of social skills at school for children with autism spectrum disorders. *Journal of child psychology and psychiatry, and allied disciplines*, 53(4):431–9, apr 2012. ISSN 1469-7610. doi: 10.1111/j.1469-7610.2011.02493.x. 17

F. Ke and T. Im. Virtual-Reality-Based Social Interaction Training for Children with High-Functioning Autism. *The Journal of Educational Research*, 106(6):441–461, nov 2013. ISSN 0022-0671. 33

W. Keay-Bright. The Reactive Colours Project: Demonstrating Participatory and Collaborative Design Methods for the Creation of Software for Autistic Children. jan 2007. 35

S. J. Kerr, H. R. Neale, and S. V. G. Cobb. Virtual environments for social skills training. In *Proceedings of the fifth international ACM conference on Assistive technologies - Assets '02*, page 104, New York, New York, USA, jul 2002. ACM Press. 32

J. Kim, T. Wigram, and C. Gold. The effects of improvisational music therapy on joint attention behaviors in autistic children: a randomized controlled study. *Journal of autism and developmental disorders*, 38(9): 1758–66, oct 2008. ISSN 0162-3257. 21

Y. S. Kim, B. L. Leventhal, Y.-J. Koh, E. Fombonne, E. Laska, E.-C. Lim, K.-A. Cheon, S.-J. Kim, Y.-K. Kim, H. Lee, D.-H. Song, and R. R. Grinker. Prevalence of Autism Spectrum Disorders in a Total Population Sample. *American Journal of Psychiatry*, 168(9):904–912, sep 2011. ISSN 0002-953X. doi: 10.1176/appi.ajp.2011.10101532. 14

J. Kimball, E. Kinney, B. Taylor, and R. Stromer. Video enhanced activity schedules for children with autism: A promising package for teaching social skills. 27(3):280–298. 30

A. Klin, F. R. Volkmar, S. S. Sparrow, D. V. Cicchetti, and B. P. Rourke. Validity and neuropsychological characterization of Asperger syndrome: convergence with nonverbal learning disabilities syndrome. *Journal of child psychology and psychiatry, and allied disciplines*, 36(7):1127–40, oct 1995. ISSN 0021-9630. 18

A. Klin, W. Jones, R. Schultz, and F. Volkmar. The enactive mind, or from actions to cognition: lessons from autism. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 358(1430): 345–60, feb 2003. ISSN 0962-8436. doi: 10.1098/rstb.2002.1202. 16

A. Klin, D. J. Lin, P. Gorrindo, G. Ramsay, and W. Jones. Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature*, 459(7244):257–61, may 2009. ISSN 1476-4687. 72

R. I. Koegel and W. D. Frea. Treatment of social behavior in autism through the modification of pivotal social skills. *Journal of Applied Behavior Analysis*, 26(3):1297760, 1993. ISSN 00218855. doi: 10.1901/jaba.1993.26-369. 154

H. Kozima, C. Nakagawa, and Y. Yasuda. Interactive robots for communication-care: a case-study in autism therapy. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005.*, pages 341–346. IEEE, 2005. 33

M. W. Krueger. Responsive environments. In *Proceedings of the June 13-16, 1977, national computer conference on - AFIPS '77*, page 423, New York, New York, USA, jun 1977. ACM Press. doi: 10.1145/1499402.1499476. 2

M. W. Krueger, T. Gionfriddo, and K. Hinrichsen. VIDEOPLACE – An Artificial Reality. In *CHI '85 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, volume 16, pages 35–40. ACM, apr 1985. doi: 10.1145/317456.317463. 2

J. M. Laffey, M. Schmidt, J. Stichter, C. Schmidt, and S. P. Goggins. iSocial: a 3D VLE for youth with autism. In *Proceedings of the 8th International Conference on Computer Supported Collaborative Learning, CSCL'09, Rhodes, Greece, June 8-13, 2009, Volume 2*, pages 112–114, jan 2009. 34

A. E. Lane, R. L. Young, A. E. Z. Baker, and M. T. Angley. Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders*, 40(1):112–122, jan 2010. ISSN 01623257. doi: 10.1007/s10803-009-0840-2. 151

D. B. LeGoff. Use of LEGO as a therapeutic medium for improving social competence. *Journal of autism and developmental disorders*, 34(5):557–71, oct 2004. ISSN 0162-3257. 19

D. B. Legoff and M. Sherman. Long-term outcome of social skills intervention based on interactive LEGO play. *Autism : the international journal of research and practice*, 10(4):317–29, jul 2006. ISSN 1362-3613. 20

H. A. Lim and E. Draper. The effects of music therapy incorporated with applied behavior analysis verbal behavior approach for children with autism spectrum disorders. *Journal of music therapy*, 48(4):532–50, jan 2011. ISSN 0022-2917. 21

S. E. Lindley, J. Le Couteur, and N. L. Berthouze. Stirring up experience through movement in game play. In *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, page 511, New York, New York, USA, apr 2008. ACM Press. ISBN 9781605580111. doi: 10.1145/1357054.1357136. 2

T. Liu. Sensory processing and motor skill performance in elementary school children with autism spectrum disorder. *Perceptual and motor skills*, 116 (1):197–209, feb 2013. ISSN 0031-5125. 18

D. Loomis, R. Holt, J. C. Kaufman, and A. S. Kaufman. Kaufman Assessment Battery for Children. In I. B. Weiner and W. E. Craighead, editors, *The Corsini Encyclopedia of Psychology*. John Wiley & Sons, Inc., Hoboken, NJ, USA, jan 2010. doi: 10.1002/9780470479216.corpsy0486. 91

C. Lord, M. Rutter, and A. Le Couteur. Autism Diagnostic Interview-Revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of autism and developmental disorders*, 24(5):659–85, oct 1994. ISSN 0162-3257. 15, 90

C. Lord, S. Risi, L. Lambrecht, E. H. Cook, B. L. Leventhal, P. C. DiLavore, A. Pickles, and M. Rutter. The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of autism and developmental disorders*, 30(3):205–23, jun 2000. ISSN 0162-3257. 14, 51, 90

O. I. Lovaas. Behavioral treatment and normal educational and intellectual functioning in young autistic children. 22, 70, 75

D. Luckevich. *Computer assisted instruction for teaching vocabulary to a child with autism*. PhD thesis, Nova Southeastern University, 2008. 30

J. Luiselli, F. Happé, H. Hurst, S. Freeman, G. Goldstein, C. Mazefsky, A. S. Carter, A. S. Kaufman, E. S. Simmons, E. R. Eernisse, K. Tsatsanis, F. Fluit, B. Klein-Tasman, A. Feinstein, A. Kahl, S. Poyau, C. R. G. Jones, F. R. Volkmar, J. M. Wolf, A. Nadig, P. Cavanagh, R. Paul, and D. B. Newman. Wechsler Preschool and Primary Scale of Intelligence. In J. S. Kreutzer, J. DeLuca, and B. Caplan, editors, *Encyclopedia of Autism Spectrum Disorders*, pages 3351–3360. Springer New York, New York, NY, 2013. doi: 10.1007/978-1-4419-1698-3{_}866. 91

M. MacDonald, C. Lord, and D. A. Ulrich. Motor skills and calibrated autism severity in young children with autism spectrum disorder. *Adapted physical activity quarterly : APAQ*, 31(2):95–105, apr 2014. ISSN 1543-2777. 18, 72, 174

G. Mahoney and F. Perales. Using Relationship-Focused Intervention to Enhance the Social Emotional Functioning of Young Children with Autism Spectrum Disorders. *Topics in Early Childhood Special Education*, 23(2): 74–86, jan 2003. ISSN 0271-1214. 19

L. Malinverni and N. Pares. Learning of Abstract Concepts through Full-Body Interaction: A Systematic Review. *Journal of Educational Technology & Society*, 17(4):100 – 116, 2014. 26

L. Malinverni, J. Mora-Guiard, and N. Pares. Towards methods for evaluating and communicating participatory design: A multimodal approach. *International Journal of Human-Computer Studies*, page Manuscript submitted for publication., mar 2016. ISSN 10715819. doi: 10.1016/j.ijhcs.2016.03.004. 126

S. Marwecki, R. Rädle, and H. Reiterer. Encouraging collaboration in hybrid therapy games for autistic children. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*, page 469, New York, New York, USA, apr 2013. ACM Press. ISBN 9781450319522. doi: 10.1145/2468356.2468439. 32

D. W. Massaro and A. Bosseler. Read my lips: The importance of the face in a computer-animated tutor for vocabulary learning by children with autism. *Autism : the international journal of research and practice*, 10 (5):495–510, sep 2006. ISSN 1362-3613. 30

L. C. Mechling, D. L. Gast, and B. A. Cronin. The Effects of Presenting High-Preference Items, Paired With Choice, Via Computer-Based Video Programming on Task Completion of Students With Autism. *Focus on Autism and Other Developmental Disabilities*, 21(1):7–13, jan 2006. ISSN 1088-3576. doi: 10.1177/10883576060210010201. 29, 30

M. Merleau-Ponty. *Phenomenology of Perception*. Psychology Press, ilustrated edition, 2002. ISBN 0415278414, 9780415278416. 23

L. Millen, R. Edlin-White, and S. Cobb. The development of educational collaborative virtual environments for children with autism. *... of the 5th Cambridge Workshop on ...*, 2010. 30

P. Mirenda. Toward Functional Augmentative and Alternative Communication for Students With Autism. *Language Speech and Hearing Services in Schools*, 34(3):203, jul 2003. ISSN 0161-1461. doi: 10.1044/0161-1461(2003/017). 29

P. Mitchell, S. Parsons, and A. Leonard. Using virtual environments for teaching social understanding to 6 adolescents with autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, 37(3):589–600, mar 2007. ISSN 01623257. doi: 10.1007/s10803-006-0189-8. 32

D. Moore, P. McGrath, N. J. Powell, and Y. Cheng. Collaborative Virtual Environment Technology for People With Autism. *Focus on Autism and Other Developmental Disabilities*, 20(4):231–243, jan 2005. ISSN 1088-3576. doi: 10.1177/10883576050200040501. 29

M. Moore and S. Calvert. Brief Report: Vocabulary Acquisition for Children with Autism: Teacher or Computer Instruction. *Journal of Autism and Developmental Disorders*, 30(4):359–362. ISSN 1573-3432. doi: 10.1023/A:1005535602064. 28

M. Nielsen, M. Störring, T. B. Moeslund, and E. Granum. A Procedure for Developing Intuitive and Ergonomic Gesture Interfaces for HCI. In

Gesture-Based Communication in Human-Computer Interaction, pages 409–420. 2004. doi: 10.1007/978-3-540-24598-8{_}38. 27

C. K. Nikopoulos and M. Keenan. Promoting social initiation in children with autism using video modeling. *Behavioral Interventions*, 18(2):87–108, apr 2003. ISSN 1072-0847. 17, 73

P. HEATON, B. HERMELIN, and L. PRING. Can children with autistic spectrum disorders perceive affect in music? An experimental investigation. *Psychological Medicine*, 29(06):1405–1410, nov 1999. ISSN 1469-8978. 21

K. Pajareya and K. Nopmaneejumruslers. A pilot randomized controlled trial of DIR/FloortimeTM parent training intervention for pre-school children with autistic spectrum disorders. *Autism : the international journal of research and practice*, 15(5):563–77, sep 2011. ISSN 1461-7005. 19

N. Parés and D. Altimira. Analyzing the Adequacy of Interaction Paradigms in Artificial Reality Experiences. *HumanComputer Interaction*, 28(2):77–114, 2013. ISSN 0737-0024. doi: 10.1080/07370024.2012.688469. 108, 150, 153, 157, 168

N. Parés and R. Parés. Interaction-Driven Virtual Reality Application Design (A Particular Case: El Ball del Fanalet or Lightpools). *Presence: Teleoperators and Virtual Environments*, 10(2):236–245, 2001. ISSN 1054-7460. doi: 10.1162/105474601750216830. 44

N. Parés and R. Parés. Towards a Model for a Virtual Reality Experience: The Virtual Subjectiveness. *Presence: Teleoperators and Virtual Environments*, 15(5):524–538, oct 2006. ISSN 1054-7460. doi: 10.1162/pres.15.5.524. 150

N. Parés, P. Masri, G. van Wolferen, and C. Creed. Achieving dialogue with children with severe autism in an adaptive multisensory interaction: the "MEDIAte" project. *IEEE transactions on visualization and computer graphics*, 11(6):734–43, jan . ISSN 1077-2626. 28, 34, 39, 42, 44, 152

S. Parsons and P. Mitchell. The potential of virtual reality in social skills training for people with autistic spectrum disorders. *Journal of intellectual disability research : JIDR*, 46(Pt 5):430–43, jun 2002. ISSN 0964-

2633. 32

S. Parsons, A. Leonard, and P. Mitchell. Virtual environments for social skills training: comments from two adolescents with autistic spectrum disorder, sep 2006. 29

L. M. Passerino and L. M. C. Santarosa. Autism and digital learning environments: Processes of interaction and mediation. *Computers & Education*, 51(1):385–402, aug 2008. ISSN 03601315. 30

M. Perkins. Preschool Children with Inadequate Communication: Developmental Language Disorder, Autism, Mental Deficiency. *Archives of Disease in Childhood*, 76(5):480–480, may 1997. ISSN 0003-9888. doi: 10.1136/adc.76.5.480c. 18

C. A. Pop, R. Simut, S. Pintea, J. Saldien, A. Rusu, D. David, J. Vanderfaeillie, D. Lefeber, and B. Vanderborght. Can the Social Robot Probo Help Children with Autism to Identify Situation-Based Emotions? A Series of Single Case Experiments. *International Journal of Humanoid Robotics*, 10(03):1350025, sep 2013. ISSN 0219-8436. doi: 10.1142/S0219843613500254. 33

K. Porayska-Pomsta, C. Frauenberger, H. Pain, G. Rajendran, T. Smith, R. Menzies, M. E. Foster, A. Alcorn, S. Wass, S. Bernadini, K. Avramides, W. Keay-Bright, J. Chen, A. Waller, K. Guldberg, J. Good, and O. Lemon. Developing technology for autism: an interdisciplinary approach. *Personal and Ubiquitous Computing*, 16(2):117–127, may 2011. ISSN 1617-4909. 34, 35, 143

M. Prensky. Digital game-based learning. *Computers in Entertainment*, 1 (1):21, oct 2003. ISSN 15443574. 27

P. A. Rao, D. C. Beidel, and M. J. Murray. Social skills interventions for children with Asperger's syndrome or high-functioning autism: a review and recommendations. *Journal of autism and developmental disorders*, 38(2):353–61, feb 2008. ISSN 0162-3257. 18

C. S. Rayner. Video-modelling to improve task completion in a child with autism. *Developmental neurorehabilitation*, 13(3):225–30, jan 2010. ISSN 1751-8431. 75

B. Reichow, E. E. Barton, B. A. Boyd, and K. Hume. Early intensive behavioral intervention (EIBI) for young children with autism spectrum disorders (ASD). *The Cochrane database of systematic reviews*, 10:CD009260, jan 2012. ISSN 1469-493X. 21

M. Resnick. Rethinking Learning in the Digital Age. In T. G. I. T. R. R. f. t. N. W. O. U. Press, editor, *The Global Information Technology Report 2001-2002*, chapter 3, pages 32–37. 2002. 27

G. Revelle. Applying developmental theory and research to the creation of educational games. *New directions for child and adolescent development*, 2013(139):31–40, jan 2013. ISSN 1534-8687. 26

B. Robins, P. Dickerson, P. Stribling, and K. Dautenhahn. Robot-mediated joint attention in children with autism: A case study in robot-human interaction. *Interaction Studies*, 5(2):161–198, 2004. ISSN 1572-0373. 31

H. Roeyers. A Peer-Mediated Proximity Intervention to Facilitate the Social Interactions of Children with a Pervasive Developmental Disorder. *British Journal of Special Education*, 22(4):161–64, nov 1994. ISSN ISSN-0952-3383. 16, 27, 73

S. J. Rogers. Interventions that facilitate socialization in children with autism. *Journal of autism and developmental disorders*, 30(5):399–409, oct 2000. ISSN 0162-3257. 16, 27

C. M. Rowland and P. D. Schweigert. Object lessons: How children with autism spectrum disorders use objects to interact with the physical and social environments. *Research in Autism Spectrum Disorders*, 3(2):517–527, apr 2009. ISSN 17509467. 19, 151

D. C. Russo and R. L. Koegel. A method for integrating an autistic child into a normal public-school classroom. *Journal of applied behavior analysis*, 10(4):579–90, jan 1977. ISSN 0021-8855. 72

F. J. Sansosti and K. A. Powell-Smith. Using Computer-Presented Social Stories and Video Models to Increase the Social Communication Skills of Children With High-Functioning Autism Spectrum Disorders. *Journal of Positive Behavior Interventions*, 10(3):162–178, jul 2008. ISSN 1098-3007. 33

M. Schmidt, J. Laffey, J. Stichter, S. Goggins, and C. Schmidt. The Design of iSocial: A Three Dimensional, Multiuser, Virtual Learning Environment for the Treatment of Autism Spectrum Disorders. jan 2008. 34

S. Steffenburg and C. Gillberg. Autism and autistic-like conditions in Swedish rural and urban areas: a population study. *The British journal of psychiatry : the journal of mental science*, 149:81–7, jul 1986. ISSN 0007-1250. 51

J. Stephenson and L. Limbrick. A Review of the Use of Touch-Screen Mobile Devices by People with Developmental Disabilities. *Journal of Autism and Developmental Disorders*, 45(12):3777–3791, dec 2015. ISSN 0162-3257. doi: 10.1007/s10803-013-1878-8. 153

P. S. Strain. Generalization of autistic children's social behavior change: Effects of developmentally integrated and segregated settings. *Analysis and Intervention in Developmental Disabilities*, 3(1):23–34, jan 1983. ISSN 02704684. doi: 10.1016/0270-4684(83)90024-1. 116

P. S. Strain, M. M. Kerr, and E. U. Ragland. Effects of peer-mediated social initiations and prompting/reinforcement procedures on the social behavior of autistic children. *Journal of autism and developmental disorders*, 9 (1):41–54, mar 1979. ISSN 0162-3257. 17, 73

D. Strickland. A Virtual Reality Application with Autistic Children. *Presence: Teleoperators and Virtual Environments*, 5(3):319–329, jan 1996. ISSN 1054-7460. doi: 10.1162/pres.1996.5.3.319. 30

D. C. Strickland, D. McAllister, C. D. Coles, and S. Osborne. An Evolution of Virtual Reality Training Designs for Children With Autism and Fetal Alcohol Spectrum Disorders. *Topics in language disorders*, 27(3):226–241, jul 2007. ISSN 0271-8294. 34

W. Symes and N. Humphrey. School factors that facilitate or hinder the ability of teaching assistants to effectively support pupils with autism spectrum disorders (ASDs) in mainstream secondary schools. *Journal of Research in Special Educational Needs*, 11(3):153–161, nov 2011. ISSN 14713802. doi: 10.1111/j.1471-3802.2011.01196.x. 17

H. Tager-Flusberg and R. M. Joseph. Identifying neurocognitive phenotypes in autism. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 358(1430):303–14, feb 2003. ISSN 0962-8436. doi: 10.1098/rstb.2002.1198. 14

A. Tartaro and J. Cassell. Playing with virtual peers: bootstrapping contingent discourse in children with autism. pages 382–389, jun 2008. 29

M. Tentori and G. R. Hayes. Designing for interaction immediacy to enhance social skills of children with autism. In *Proceedings of the 12th ACM international conference on Ubiquitous computing - Ubicomp '10*, page 51, New York, New York, USA, sep 2010. ACM Press. ISBN 9781605588438. doi: 10.1145/1864349.1864359. 29, 30

L. Tolentino, D. Birchfield, and A. Kelliher. SMALLab for Special Needs: Using a Mixed-Reality Platform to Explore Learning for Children with Autism. 34

M. Tuedor. Universal access through accessible computer educational programs to develop the reading skills of children with autistic spectrum disorders. *Universal Access in the Information Society*, 5(3):292–298, aug 2006. ISSN 1615-5289. doi: 10.1007/s10209-006-0047-7. 30

J. N. van der Geest, C. Kemner, G. Camfferman, M. Verbaten, and H. van Engeland. Looking at Images with Human Figures: Comparison Between Autistic and Normal Children. *Journal of Autism and Developmental Disorders*, 32(2):69–75. ISSN 1573-3432. doi: 10.1023/A:1014832420206. 16

L. Villafuerte, M. Markova, and S. Jorda. Acquisition of social abilities through musical tangible user interface. In *Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts - CHI EA '12*, page 745, New York, New York, USA, may 2012. ACM Press. 32

G. Vivanti, C. Dissanayake, C. Zierhut, and S. J. Rogers. Brief report: Predictors of outcomes in the Early Start Denver Model delivered in a group setting. *Journal of autism and developmental disorders*, 43(7): 1717–24, jul 2013. ISSN 1573-3432. 21

Z. Warren, M. L. McPheeters, N. Sathe, J. H. Foss-Feig, A. Glasser, and

J. Veenstra-Vanderweele. A systematic review of early intensive intervention for autism spectrum disorders. *Pediatrics*, 127(5):e1303–11, may 2011. ISSN 1098-4275. 18, 72

D. Wechsler. *Wechsler Intelligence Scale for Children.* 1949. 90, 133

P. L. Weiss, E. Gal, S. Eden, M. Zancanaro, and F. Telch. Usability of a multi-touch tabletop surface to enhance social competence training for children with Autism Spectrum Disorder. In S. E. Y. Eshet-Alkalai, A. Caspi and Y. Y. en, N. Geri, editors, *71 Patrice L. (Tamar) Weiss, Eynat Gal, Sigal Eden, Massimo Zancanaro, Francesco Telch Proceedings of the Chais conference on instructional tec hnologies research 2011: Learning in the technological era*, pages 71–78, Raanana, 2011. 31

J. V. Wertsch. *The Concept of Activity in Soviet Psychology.* M. E. Sharpe, Armonk, 1981. 24

J. V. Wertsch. *Vygotsky and the social formation of mind.* 1985. 24

T. Wigram. Clinical Improvisation Skills for Music Therapy Practice and Music Therapy Training Programs. 2004. 21

E. Williams. A comparative review of early forms of object-directed play and parent-infant play in typical infants and young children with autism. *Autism : the international journal of research and practice*, 7(4):361–77, dec 2003. ISSN 1362-3613. 19, 151

M. Wilson. Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4):625–36, 2002. doi: 10.3758/BF03196322. 4

D. A. Zachor and E. Ben Itzchak. Treatment approach, autism severity and intervention outcomes in young children. *Research in Autism Spectrum Disorders*, 4(3):425–432, jul 2010. ISSN 17509467. 18