Analysis of Interaction Design and Evaluation Methods in Full-Body Interaction for Special Needs:

Collaborative Virtual Environments for Improving Socialization in Children with Autism

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It is our choices... that show what we truly are, far more than our abilities.

-J. K. Rowling

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Abstract

This thesis is focused on the specific properties and evaluation of full-body interaction design of multi-user mixed reality environments to aid in intervention strategies for children with autism, to improve their understanding and adoption of social behaviors with peers and with society in general. This practice-based research is based upon human-computer interaction theory, and is aided by general theories of embodied cognition, embodiment and developmental psychology. The research consists of designing playful experiences for the target users in order to promote socialization and collaboration. The design of the experiences has been informed by codesign activities and collaboration with experts in autism, parents, psychologists, therapists, caregivers and the children themselves. Topics for analysis will include understanding the dynamics of goal-oriented and open-ended gameplay, proxemics, and encouraged vs enforced collaboration on the design of these systems. Assessment methods take into account video recorded footage, system logs, user interviews and multimodal analysis, including physiology-based data such as electrodermal activity and heart rate of the childrens behavioral and affective states throughout the experience. The main setting of the research is large scale floor-projected mixed environments, enabling the testing of interaction strategies and evaluation methods of experiences based on collocation of multiple users within a full-body interactive scenario, where they can practice interaction face-to-face in a natural and uninhibited manner.

Resum

Aquesta tesi es centra en l'avaluació i les propietats específiques del disseny d'interacció a cos sencer d'entorns de realitat mixta multiusuari, dissenyats per ajudar en estratègies d'intervenció per a nens amb autisme, i millorar la seva comprensió i adopció de comportaments socials amb companys i amb la societat en general. Aquesta investigació es basa en la disciplina de la interacció persona-ordinador, informada també per teories generals de la cognició encarndada i de la psicologia del desenvolupament. Aquesta recerca consisteix en dissenyar experiències lúdiques per a la població objectiu per tal de promoure la socialització i la col·laboració. El disseny de les experiències ha estat informat per activitats de co-disseny i de col·laboració amb experts en autisme, pares, psicòlegs, terapeutes, cuidadors i els propis nens. Els temes per a l'anàlisi inclouen la comprensió de les dinàmiques de joc orientat a un objectiu i joc lliure, les proxèmiques, i la col·laboració encoratjada per al disseny d'aquests tipus de sistemes. Els mètodes d'avaluació tenen en compte les imatges enregistrades en vídeo, els registres del sistema, les entrevistes amb els usuaris i l'anàlisi multimodal; incloent dades fisiològiques, com l'activitat electrodèrmica i la freqüència cardíaca dels estats conductuals i afectius dels nens durant tota l'experiència. El context principal de la investigació són els entorns mixtos a gran escala projectats al terra, els quals permeten provar estratègies d'interacció i mètodes d'avaluació d'experiències d'interacció amb múltiples usuaris, on poden practicar la interacció cara a cara, de manera natural i desinhibida.

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Chapter **1**

Introduction

1.1 Approach

Play times such as recess provide an opportunity for classmates to share experiences and bond with their peers through face-to-face activities. However, these activities rarely take into account the unique needs and abilities of children with autism, who also stand to benefit from social integration with their peers through activities adapted to their interests.

Social inclusion is one of the primary obstacles for children with Autism Spectrum Disorders (ASD) in leading an independent life. In the case of high-functioning children with autism who are placed in mainstream school contexts, curricula and classroom activities might still be separated from their peers. As digital media tools have been seen to appeal to children with autism [Bernard-Opitz et al., 2001], [Moore and Calvert, 2000], motivating their interaction with peers, we aim to explore this gap with usable classroom technologies, towards fostering social integration in children with social conditions such as autism. Through the development of interactive systems for individuals with autism, the goal is to distill a set of meaningful interaction design and evaluation criteria which can guide the developers of digital tools, based on children with autism's needs and abilities, empowering them to make meaningful use of play technologies.

1.2 Motivation

Recent autism diagnostic tools have shown an evolution in detection precision, currently allowing autism to be diagnosed from preschool age, which has seen a corresponding increase in prevalence of childhood autism occurrences [Charman and Baird, 2002]. As research for intervention technologies increases, many potential aids have been developed to ease the burden on parents, teachers, and professionals. Interactive tools have proven to have a positive impact on those seeking support for the difficulties related to the condition. The current technology surge places the tools for development in the hands of the user, as parents and caregivers can use these tools to create customized solutions based on their own experiences needs. However, little work has focused on understanding the interaction design strategies adequate for this group of users, who possess a separate set of needs and abilities from typically developing populations.

This thesis aims to contribute a set of guidelines and theoretical foundations which will be useful for designing and developing systems for children with autism, based on a rigorous qualitative and quantitative analysis of a series of full-body interactive environments designed in our lab for this set of users. The guidelines address the design, evaluation, and interaction design principles which we have found contribute positively to socialization and collaboration interventions for autism.

The first step of this research has included reviewing work done in the field through a systematic compilation of published materials, along with consulting professionals in the field of autism therapy and autism technologies. The knowledge gained from this review has contributed to a secondary goal, which was to define interaction criteria to foster social initiation. To accomplish this, we evaluate and contribute new interaction design concepts through the development of our own novel systems. In addition to knowledge derived from external projects in the field of interactive technologies for autism, we also used the knowledge gained from our previous studies in the Full-Body Interaction Lab of the Cognitive Media Technologies Group, the principles compiled by experts in human-computer interaction, and participatory design activities with psychologists and children. The interaction criteria presented are aimed to foster social initiation which will facilitate social interaction in their future lives and allow these individuals to be more autonomous citizens.

1.3 Background

To guide the reader and provide orientation for the upcoming chapters, here we will present basic definitions and parameters which form the cornerstone of the studies described in this thesis. Specifically, this includes background information on the topics of autism, full-body interaction, and the behaviors that we refer to when we talk about socialization and collaboration.

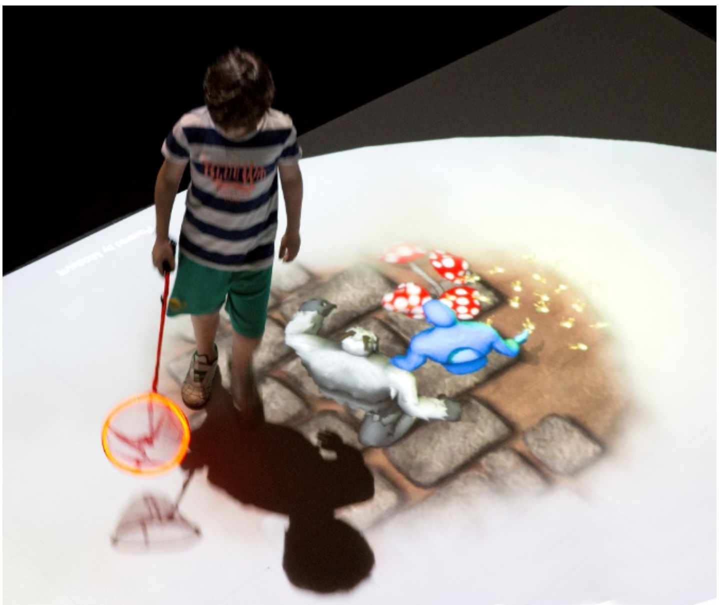


Figure 1.1: Children with Autism Spectrum Disorders may present difficulties making and maintaining friendships.

1.3.1 Autism Spectrum Disorder

Autism Spectrum Disorders are a collection of neurodevelopmental conditions affecting social communication, including lack of back-and-forth conversation, nonverbal communication and difficulties making and maintaining friendships [American Psychiatric Association, 2013]. In addition, individuals with autism may display restricted and repetitive patterns of behavior, such as motor stereotypies, inflexibility to change, and unusually specific interests.

Children with autism have shown a high affinity towards digital media, as well as high abilities in playing video-games, which has led to an increased focus the development of digital intervention tools. In the case of full-body interaction, systems can collocate multiple users in the same scenario, allowing for face-to-face communication and movement in an exploratory virtual environment (see Figure 1.1).

The contemporary understanding of autism as a specific type of human condition among the multiple conditions that exist in our society, in contrast to a disability, makes it difficult to talk of a typical population when trying to refer to that part of our society that has not been diagnosed of autism. In other words, we can only hope to distinguish between those that have been diagnosed a specific condition with respect to those that have not. Although we are aware of the difficulties in defining this “typical population”, for practical reasons in this dissertation we will use the less cumbersome formula “typically developing children” to refer to those children that have not been diagnosed with ASD.

1.3.2 Full-body interaction

Full-body interactive environments are digital media which allow interaction by the natural behaviors and gestures which we use in daily life to communicate and express ourselves, through the movements of our bodies, and through understanding ourselves as active participants in relation to the surrounding space. These technologies pose a unique stance to the interactive technologies paradigm, placing the body at the center of interaction. Related concepts include whole-body interaction, movement based interaction, and embodied interaction, each referring to slightly different but connected concepts (the latter of which will be discussed in the following chapter).

We understand that the full-body interaction paradigm encompasses all interactive media that sets the body and physical activity as the main means for communicating with the system. Full-body interaction technologies allow for a wide range of sensorimotor activities in forming the relationship between the user and the virtual environment. Moreover, full-body experiences can allow for face-to-face collaboration with other users during the interactive experience without the necessity of intermediary physical interfaces. These systems can mediate this face-to-face interaction between the users. Therefore, we are designing and trying to understand this user-to-user interaction through the mediation of the system. Research has shown that full-body interaction systems hold potential as intervention tools for individuals with social disabilities, such as those with autism [Mora-Guiard et al., 2017]. The current research is focused on exploring the potential of full-body interaction media for the design and development of collocated intervention tools for children with ASD, at the intersection on full-body interaction and socialization for autism (see Figure 1.2).

This thesis initially sought to create full-body interactive tools to foster social initiation in children with autism. However, through the process of creating and testing these systems, another theme has also edged its way into the experimental plan: the need to take into account not only socialization but also *collaboration* between participants acting together in the environments. Socialization and collaboration often appear together, and are both imperative to cognitive development and functioning in children growing up in advanced societal structures [Vygotsky, 1967]. Socialization is often seen as a precursor to collaboration, and collaboration might be impossible or limited at best if not for the communication which socialization contributes. Although they may appear side by side in this thesis, social-

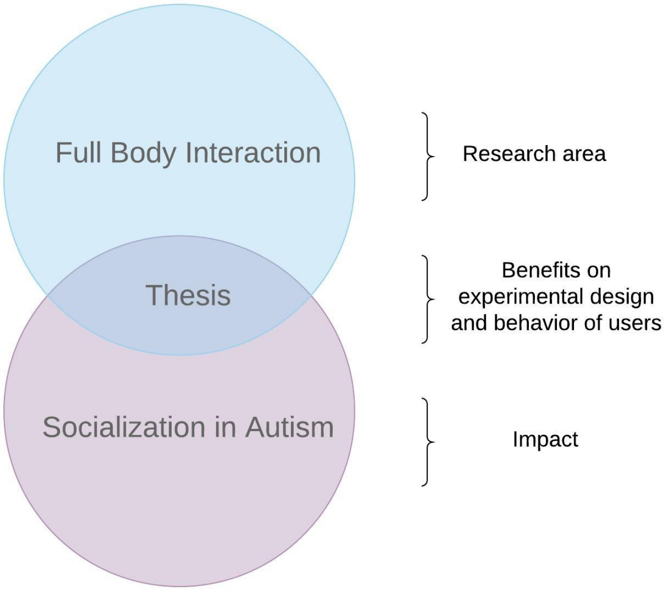


Figure 1.2: This research is found at the intersection of full-body interaction and socialization for autism.

ization and collaboration are separate concepts and must be referred to by their similarities as well as their differences. Therefore, I would like to take this moment to lay out the distinction.

1.3.3 Socialization

Socialization is understood as the process by which a child adjusts to society, whereby internalizing the customs and norms that govern contact with others [Little and McGivern, 2014]. Socialization is a crucial part of human development; it is through this external contact and sharing of concepts that individuals begin to integrate into society and form a sense of self. Sociologists study how culture and society shape the mind of individuals. Erik Erikson's work on psycho-social development is based upon the idea that emotional structures are created throughout childhood, and influenced by societal and cultural patterns around us [Erikson, 1950]. Jean Piaget later explored how social interactions play into child development, laying the foundations for our modern understanding of developmental psychology [Piaget, 1954].

Socializing is when individuals are engaged in communication with others [Little and McGivern, 2014], and seeking this act served as the goal of several of the projects in this thesis. In discussing socialization in this thesis, we are most often referring to a set of social interaction behaviors in which the child displays a willingness to engage in playful and positive interactions with other. Our criteria for classifying these interactions has been derived from the existing literature on coding and analysis of social behaviors in motion-based games [Bianchi-Berthouze et al., 2007] and those used in clinical research and interventions for children with autism [Bauminger, 2002]. These codes take into account not only the behavioral tendencies of children with autism, but also their capabilities from a developmental standpoint. A few of these behaviors include social initiations, response to the initiation of another, eye contact, shared interest, and asking for help/giving help. We will describe how we have chosen and adapted these particular behaviors in detail in Chapter 6 of this thesis. In some projects, we have also carried out quantitative analysis of social behaviors through identifying and categorizing social acts, including language used to share discoveries in a play environment.

For children with autism, it has been seen that individuals are more likely to continue interactions that have already started than to initiate conversations themselves [Bauminger, 2002]. Because we view initiation as a facet of socializing that leads to extended social contact, we have focused particularly on social initiation as a goal of the projects in this thesis.

Although we frame our understanding of socialization within this list of discrete social behaviors, the larger goal we kept in mind for the projects was to foster a positive attitude towards socialization with peers. This meant not only making decisions that would lead to social behaviors, but also taking into account the effects of playing with a partner, the ways that this could positively and negatively affect the individual, and the meaningful experience of the children.

1.3.4 Collaboration

Collaboration is an interpersonal process which occurs when two or more people coordinate related actions to achieve a common goal. Social activities such as collaboration lead to the development of cognitive skills based on active participation in the environment and learning from the tools and conversations within the social context [Rogoff, 1990]. From a developmental stance, Broadhead argues that early play and learning contribute to communication skills in children, moving from non-reciprocal to reciprocal language through collaborative play with others [Broadhead, 1951].

Collaboration calls for a shared understanding on a common focus of attention, which forms the grounds for communication. According to Vygotsky, the human mind is inherently social, and the development of cognitive processes is mediated by discourse and intersubjectivity [Wertsch, 1985], using tools such as verbal and non-verbal language [Forman, 1992].

Collaborative scenarios can be beneficial to practice social skills for individuals with social difficulties, such as children with autism, which has been a key point for this research. Mundy et al. observed that individuals with autism showed significant deficits in the use of joint-attention abilities, or "coordinated attention between interactive social partners with respect to objects or events in order to share an awareness" [Mundy et al., 1986]. As collaboration is agreed upon through social communication, collocated mediated collaborative scenarios present an ideal approach for individuals with ASD to scaffold the learning of social behaviors.

Through collaborative settings, social behaviors are put into practice in a scenario where participants of the task have a shared goal, such as a problem solving situation. Thus, collaboration is built upon three processes: communication between group members, coordination of shared goals and responsibilities, and problem solving of given tasks [Dillenbourg, 2002].

This thesis has worked to develop an understanding of *encouraged collaboration* as a means of enticing users to work together through positive reinforcement, as opposed to *enforced collaboration*. This concept has been implemented in the projects discussed in Chapter 4, and will be discussed in greater detail in Chapter 5.

1.4 Research Objectives

To carry out this research work, an understanding was first developed of the current state of autism diagnosis and digital intervention tools (Chapter 2). Specific focus was placed on tools which utilize virtual environments for autism social skills intervention. A research plan was then developed to better understand the impact of interaction design in these interventions, specifically using full-body interaction environments for autism. The research plan included the design and testing of three full-body interaction environments, then from the data collected, analyzing which aspects of the systems which led to social and collaborative behaviors.

The first phase of research included the design and testing of a large scale full-body interactive environment called Lands of Fog. I joined the project in the late prototyping design phase and developed the experimental design, contributed to running trials in Barcelona and London, and led the data analysis. Through multimodal data analysis, it was discovered that children were in fact interacting with their peers increasingly over the course of the sessions, but it was not clear how the environment might have affected their internal state during the experience. Using data and observations from the initial trials, I proposed and designed a second version of the game with variations in the interaction design and two alternate scenarios: goal oriented and open-ended. In addition, it was proposed that physiological sensing be included in the data collection to better understand the children's state while playing. I worked on an experimental design which was developed to test the second version of the game with physiological data (Chapter 4), as we attempted to triangulate specific interaction design components such as collaboration mechanics, open-ended play, proxemics, and contextual elements (Chapter 5).

Seeing that Lands of Fog had positive results in fostering socialization, I then developed a spin-off project called GenPlay (Chapter 4), inspired by the interaction paradigms of Lands of Fog but adapted to a classroom environment. For this project, I led the ideation phase, design sprint sessions, oversaw the development phase and ran the iterative prototype testing in Barcelona. After the development of a final prototype, I tested the system in the Netherlands, in an elementary school setting.

This thesis includes outcomes from these projects related to both systems' propensity for fostering socialization between children with autism (Chapter 4), and an analysis of the specific interaction design concepts which I believe have impacted these results (Chapter 5).

Finally, as we did not find evaluation tools which were adequate for the observation of social behaviors in children with autism in collaborative virtual environments, I have led the search for novel evaluation methods based on the psychological profile of children with autism, described in Chapter 6.

1.4.1 Goals

This research aims to investigate how full-body interactive environments can aid in intervention tools for children with autism. Specifically, the research will include an analysis of the interaction design parameters which lead to socialization in digital media-based interventions for autism. The research aims to contribute with a relevant analysis of interaction design concepts in projects for autism, and also creates a set of guidelines for other designers based upon outcomes of the research.

As children with ASD display difficulties in forming and maintaining relationships with peers, we see that full-body interactive systems present an opportunity for children to practice social behaviors face-to-face while engaging in a playful collaborative experience with peers. As opposed to non-digital games, interactive environments are able to adapt and respond to changes in user behavior, adding consistency and challenges to keep the users motivated. Therefore, with the use of full-body interactive systems, our primary goal would be to heighten the understanding and adoption of social behaviors by children with ASD, leading to a higher propensity for inclusion with peers in collaborative settings.

In reviewing current work done in the field, several key areas of interest have emerged which lack resolutions or further research. Research into these areas could be useful in creating new full-body interaction systems for children with ASD. One of these areas is understanding the role of proxemics and its nuances in the spatial perception of children with ASD in collaborative systems. As personal space has an effect upon the feelings evoked while playing a game collaboratively with another person, it is understood to be a useful consideration for designers to engage players. Although notable research had been done in the field of using proxemics for interactive experiences, there had yet to emerge a clear understanding of proxemic understanding with children with ASD. As children with ASD typically demonstrate unconventional understandings of social boundaries, research into this field could provide interesting insights into building play experiences for these individuals.

Other areas of research which will be discussed include gaming structure elements of encouraged collaboration and open-ended play. Encouraged collaboration is the practice of giving players the option to collaborate, with added incentives as opposed to playing alone. This is intended to bring users together by their own volition, while retaining the comfort of solitary play, as opposed to enforced collaboration, where players cannot play the game without collaborating.

Research which has been done on designing interactive objects with games has aimed to understand the different playing modes which users embrace with and without the presence of a goal. With no goal, players are free to decide their own narratives, using their creative instincts. This research, however, lacks a quantitative evaluation of when players with autism show higher levels of meaningful socialization. As many interactive experiences for children with ASD typically have a goal of heightened socialization, understanding the link between goal oriented play or open-ended gameplay and socialization levels could prove useful for game designers working with autism interventions.

Finally, this research will aim to develop structured methods for evaluation in interactive technologies where children with autism practice socialization and collaboration. The studies in this thesis were not only meant to increase children's levels of socialization, but also to better understand how and when they collaborate and changes in their emotional experience when playing. This evaluation includes both qualitative methods, such as video coding sessions, and also quantitative analysis of game logs and biometric feedback. The goal is to form a protocol which can be used to determine the efficacy of ASD social interventions where users play in an open format.

In addition to forming a comprehensive understanding of current practices in developing social intervention systems for autism, this research aims to respond to the following questions:

1. How can we improve the understanding and adoption of social behaviors and heighten inclusion with peers and society in general through the design of full-body interactive systems to aid in intervention strategies for children with ASD?

2. How can we better understand the interaction design aspects which create socialization, collaboration, and engagement in interactive games for ASD, such as encouraged collaboration, proxemics and open-ended play?

3. What evaluation methods can be effective for systems which foster socialization and collaboration in multiuser, spontaneous play based systems for children with ASD, designed using full-body interactive technology?

4. What design and evaluation guidelines can aid other designers based on the outcomes of the research projects?

1.5 Structure of the thesis

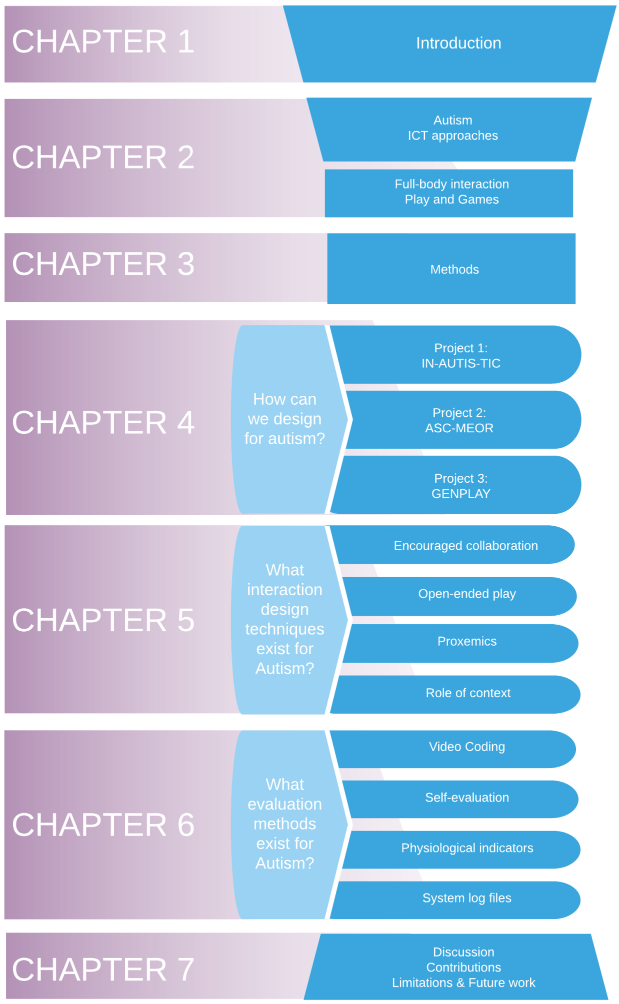


Figure 1.3: The topics discussed in this thesis are divided into seven chapters.

This work aims to advance in understanding how full-body interactive technologies can better foster social initiation behaviors in children with ASD. Also, we would like to advance in understanding how full-body interaction affects user interaction in general and in the case of individuals with ASD, to help psychologists with the design and implementation of interventions and advance in the integration of ASD children in society by raising awareness of what autism is. Finally, we aim to advance in the development of interactive tools to help in intervention and therapy, for psychologists, therapists, caregivers, educators, and parents.

The second chapter will introduce relevant work and concepts in the field of interactive technologies for autism (see figure 1.3). We will also provide background information on autism, including diagnosis methods and cognitive theories. Methods will be introduced in Chapter 3, and Chapter 4 will discuss three projects which have been developed through the course of this thesis. The description of each project will focus on relevant design and development practices, and will conclude with results of the primary research questions addressed. Also, we discuss the benefits of full-body interactive systems as free play environments for multiple users, their potential for exploratory and spontaneous collaborative play, which builds upon our previous work in social therapies for children with ASD. Chapter 5 will include a discussion of the interaction design principles which have been tested in these full-body interaction systems for autism, including collaboration mechanics, proxemics, open-ended play and contextual elements. Chapter 6 will discuss methodologies and development of the evaluation methods implemented, with specific focus on video coding and behavioral indexing for virtual environments for autism. Chapter 7 will include a discussion of the ideas presented in the previous chapters, linking concepts from the perspectives of design, implementation, and evaluation of full-body virtual environments for autism. A summary and opportunities for future work will be presented at the end of Chapter 7.

Chapter 2

Research Context

2.1 Introduction to this chapter

In this chapter, we will begin by introducing Autism Spectrum Disorders and the unique characteristics which shape the lives of these individuals. As the works contained in this thesis were developed to address social interaction, we will specifically focus on the difficulties which individuals with autism face in social settings and integrating into society. Next, full-body interaction will be introduced as the media which forms the basis of this thesis. The relevance of this human-computer interaction paradigm in working with children with autism will be discussed, based upon the theoretical underpinnings of embodied cognition. We will review how these projects fit within the wider span of digital technologies for autism intervention, along with reviewing related work which forms the inspiration for the projects developed in the subsequent chapters. We will also highlight the foundations of play and games, and discuss the potential for play-based therapies for autism. Along with this, we will discuss relevant aspects of designing digital play systems, such as open-ended play, play phases, proxemics, and designing for special needs. This chapter will conclude with a description of the methods used in the design, development, and testing of the projects in this thesis.

2.2 Autism Spectrum Disorder

Autism Spectrum Disorders are a collection of neurodevelopmental conditions which impact an individual's disposition for social communication and social interaction [American Psychiatric Association, 2013]. Although people with ASD show a wide range of intellectual and motor capabilities [Tager-Flusberg and Joseph, 2003], there are a few characteristics which are particularly common among diagnosed individuals. These include inhibitions in social communication and restricted patterns of behavior, interests, and activities. Other criteria may include difficulties adjusting behavior in social contexts, insistence on routines or rigid patterns of thought, and repetitive speech or movements. Children with autism may also display an extreme attention towards sensory aspects of the environment, including specific sounds or textures. A full list of criteria used for diagnosis of autism may be found in the Diagnostic and Statistical Manual of Mental Disorders V (DSM-V, [American Psychiatric Association, 2013]).

2.2.1 Diagnosis

The characteristics of autism are present from the first phases of development, and the condition may reliably be diagnosed from 2 years of age, at which point parents may choose to screen their child for autism. Common screening tools include the Social Communication Questionnaire [Rutter et al., 2008] and the Child Behavior Checklist [Achenbach et al., 2012], which go with a structured interview. Following the initial screening, a diagnosis may follow. Tools to diagnose autism include the Autism Diagnosis Observation Schedule (ADOS) [Lord et al., 2001] for young children, or the Autism Diagnostic Interview (ADI-R) [Lord et al., 1994] for adults. This diagnostic assessment includes evaluation through structured interviews and direct observation, and a diagnosis may be accompanied with an IQ measurement. The IQ can be measured using The Wechsler Intelligence Scale for Children (WISC) [Wechsler, 1949] or Developmental Scale tools, such as Vineland.

According to the DSM IV and earlier, Autism Spectrum Disorders could be divided into categories such Autism, Asperger's Syndrome, and Pervasive Developmental Disorder - Not Otherwise Specified. However, according to the DSM V, these are no longer considered separate conditions, as the behavioral patterns are continuous and overlapping. Therefore, distinguishing concrete boundaries between the conditions may lead to inconsistent determinations [Chen, 2012]. For the purpose of this thesis, we will refer to the Autism Spectrum Disorders as “autism”.

After the diagnosis is made, clinical modifiers may be assigned to give more information on the childs specific case. These clinical modifiers help determine on which part of the spectrum the childs condition occurs. Examples include the presence of language delays, or catatonia.

A wide variety of symptoms exist among individuals who are diagnosed with an autism [Tager-Flusberg and Joseph, 2003]. Even people who have the same functioning level in ASD diagnostic assessments may present a wide range of symptoms, as there are no intelligence and language capabilities “typical” of autism. Nonetheless, one of the most prevailing characteristics common to individuals with ASD are difficulties in the social abilities necessary for the conventions imposed by society [Ploog et al., 2013]. Although individuals with high-functioning ASD, or individuals with an autism diagnosis and an IQ above 70 (HFASD) show normative performances in social capacities in front of structured social tests [van der Geest et al., 2002], in more spontaneous, real-time social scenarios there are discrepancies in their performance when compared to typically developing individuals with a similar IQ and age [Klin et al., 2003].

2.2.2 Social and communication difficulties

For individuals with autism, forming and maintaining relationships with peers may be challenging due to deficits in social communication skills and difficulties understanding non-literal language, such as misinterpreting meaning by relying on literal definitions of words, as opposed to contextual meanings [Grynszpan et al., 2008]. Although individuals with autism can learn to respond to the social bids of peers, they may still find it difficult to initiate social conversations [Pierce and Schreibman, 1995].

The pervasive deficits in social abilities among individuals with ASD frequently result in challenges in developing, maintaining, and understanding relationships with others. According to the DSM-V, criteria used to distinguish individuals with autism include deficiencies in socio-emotional reciprocity including failure to initiate or respond to social initiations, lack of facial expressions and nonverbal social behaviors such as anomalies in eye contact and body language, and difficulties taking part in imaginative games [American Psychiatric Association, 2013].

As a result, research on unstructured playground dynamics has suggested that children with ASD may show a higher frequency of engaging in solitary, nonsocial play than their typically developing counterparts [Symes and Humphrey, 2011], [Kasari et al., 2012], [Bauminger et al., 2010]. Even in the event that they seek involvement in activities with peers, they may not possess the communication skills necessary to create socially appropriate dialogue and integrate themselves [Bauminger-Zviely et al., 2014]. These problems may lead to increased instances of social fragmentation in school contexts for children with ASD. Thus, it might be necessary to provide support during unstructured social times to counter social fragmentation [Anderson et al., 2015].

Relationships with peers may suffer as a result of challenges in social communication abilities. 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]. Furthermore, due to these problems understanding non-verbal social cues, people with ASD have problems in social engagement, and may persist with extended discourse after the interlocutor has changed their focus of interest [Bauminger-Zviely et al., 2014]. Moreover, they might monopolize conversations or remain unaware of an interlocutor's attempts to seek response [Bailey, 2000], [Bauminger-Zviely et al., 2013].

Along with conversation, individuals with ASD also have difficulties understanding non-verbal language, which can lead to misinterpretations of unspoken social norms and expectations [De Jaegher, 2013] or an overly literal interpretation of speech [Baron-Cohen and Bolton, 1993] due to failure to detect contextual meanings of words [Grynszpan et al., 2008]. Individuals with ASD also find seeking involvement and acceptance difficult, resulting in problems carrying out collaborative tasks [van Ommeren et al., 2011].

2.2.3 Cognitive Theories

Autism is a multifaceted condition and a variety of ages, intellects, and fluctuations are encountered among individuals with ASD. Extensive research on the cause of ASD has yet to define a single cause for the condition, but has suggested rather a myriad of factors, such as genetics and environmental factors. Several prominent theories have been presented which aim to explain the cognitive underpinnings of the condition, although these theories do not represent or explain the diversity of cases present. These theories include the theory of mind, executive dysfunction, and weak central coherence.

The *theory of mind* hypothesis holds that individuals with ASD have challenges taking into account the mental states of themselves and others [Baron-Cohen, 1997]. This theory, also called Mindblindness refers to the inability of individuals with ASD to impute mental states to themselves and peers [Frith, 2001]. This may explain difficulties in forming close social bonds and understanding non-literal or non-verbal language.

Executive function refers to a collection of cognitive processes which manage goal directed behaviors, such as planning, multi-tasking and inhibition. *Executive dysfunction* refers to the difficulties engaging in these goal-directed behaviors [Hill, 2004]. The executive dysfunction hypothesis for autism may account for difficulties in switching between tasks and controlling impulsive movements. A running errands simulation experiment tested multi-tasking and the point in which participants failed to effectively carry out tasks [Rajendran et al., 2011]. It was found that inflexibility in planning and problems with prospective memory seemed to cause the most difficulties with multi-tasking among participants.

The *weak central coherence theory* aims to understand how individuals with ASD possess a tendency to focus on details while demonstrating significant difficulties in comprehending overarching contexts, or "seeing the big picture" [Happe F., 1999]. This can be observed in the tendency for children with ASD to possess specialized pockets of knowledge and abilities, while still finding it challenging to live in the real world. In many instances, children with ASD will focus more on details and rigid routines, while missing out on larger concepts.

In addition, the *Empathizing-Systemizing Theory* aims to understand why individuals with ASD construct and analyze systems more than typically developing people [Baron-Cohen et al., 2009].

In spite of the strengths of these theories in explaining the disorders typically observed in individuals with ASD, it is assumed by many that resolving a common theory might never be feasible to explain the complexity of ASD. One common assertion is that cognitive theories do not account for the bodily aspects of autism in lieu of a Cartesian view, ignoring the body in defining cognition. This has renewed an interest in *embodied cognition* theories for autism, which defends that the functionality of the mind must be understood in unison with its connection to the body. As Hanne de Jaegher [De Jaegher, 2013] explained,

> "Sense-making plays out and happens through the embodiment and situated-ness of the cognitive agent: her ways of moving and perceiving, her affect and emotions, and the context in which

> she finds herself, all determine the significance she gives to the world."

According to this explanation of the embodied cognition theory, the human experience is defined by our movement and exploration of surroundings. This theory will be discussed in further depth later in this chapter.

2.2.4 Current Therapies

Research has shown that early intervention in children with high-functioning ASD leads to better progress reports [Rao et al., 2008], [Zachor and Ben Itzchak, 2010], thus increasing the potential for an improved quality of life [Carr, 1977]. There are a number of current therapies which are used in the treatment of children with ASD.

Cognitive Behavioral Therapy

Cognitive behavioral therapy (CBT), commonly used to treat anxiety and depression, works to address problematic behaviors through working with a therapist to modify thinking and behavioral patterns. According to Moree and Davis [Moree and Davis, 2010], successful CBT for children with ASD must 1) develop disorder-specific hierarchies, 2) use specific visual tactics, 3) incorporate interests of the child and 4) include the parents.

Applied Behavioral Analysis

Applied Behavioral Analysis (ABA) uses positive reinforcements to strengthen the frequency of desired behaviors. This type of therapy has been seen to improve communication abilities, social behaviors, play skills, as well as looking and imitating, and perspective-taking [Grindle et al., 2012], [Eapen et al., 2013], [Dawson et al., 2012].

DIR/Floortime

The Developmental, Individual Differences, Relationship-Based (DIR) model for therapy uses "floortime" where parents and children play together spontaneously at ground level, following psychologist directions for building complexity in interactions. The interaction is child-led and builds upon the child's individual abilities, with reciprocal actions to encourage focus, initiation, and elaboration of ideas [Wieder and Greenspan, 2003].

2.3 ICT for Autism

While conducting research on how to engage children with ASD, Brown and Murray [Brown and Murray, 2001] found that individuals with ASD showed affinity to Information and Communication Technologies (ICT). Along with an increased interest towards science and math skills [Baron-Cohen et al., 2001], children with ASD might display a special interest in computerized learning [Bernard-Opitz et al., 2001] [Moore and Calvert, 2000] possibly due to the linear and systematic nature of most computer programs.

In an attempt to provide engaging and dynamic interventions, many research efforts have utilized Information and Communication Technologies to create interventions and learning experiences for children with ASD [Goldsmith and LeBlanc, 2004]. The clear structure of computerized systems can reduce anxiety for individuals with autism, as they usually show increased responsiveness to stimuli when events are predictable [Ferrara and Hill, 1980].

Opportunities to utilize digital-based therapies and interventions for children with ASD include: fostering language acquisition with the use of desktop media [Tentori and Hayes, 2010], [Bosseler and Massaro, 2003], [Tartaro and Cassell, 2008], aiding communication using handheld devices [Dyches et al., 2002], [Mirenda, 2003] and learning social abilities using head mounted displays [Strickland, 1996]. Game-based interventions designed for children with ASD have proven to accelerate learning processes [Charlton et al., 2004], as children have shown increased motivation to complete the required objectives [Hoque et al., 2009]. Moreover, as the efficacy of treatments for improving social functioning is mainly associated with their continuity and intensity in terms of weekly hours [Boyd et al., 2014], professionals have explored the use of digital games to complement traditional treatment methods.

Davis et al. recommended developing technological interventions with design features which would be readily accepted by individuals with autism in therapy settings, such as task consistency and predictability as well as the gradual introduction of novel elements [Davis et al., 2010]. Therefore, digital approaches are ideal as they can easily regulate change [Alcorn et al., 2011], and feedback can be programmed to be immediate and consistent [Moore and Calvert, 2000]. As digital technologies allow change to be introduced and mediated in a discreet manner, this offers a potential benefit to enhance consistency in traditional therapy settings, while introducing diversification.

There is evidence of the acquisition of diverse skills by children with ASD through digital technologies. In the domain of video modeling (e.g. teaching by displaying video recordings as a visual support) research shows that digital technologies hold potential for achieving task completion [Mechling et al., 2006][Hayes et al., 2010]. Teaching with desktop computer applications has also been successful for the acquisition of reading and listening abilities [Coleman et al., 2005][Tuedor, 2006][Luckevich, 2008]. Multimedia in handheld devices has been used for supporting the teaching of Mind Reading abilities, or the recognition of complex emotions in face and voice [Baron-Cohen et al., 2009]. This medium has also been used to teach interaction immediacy, or maintaining appropriate spatial boundaries in social interaction. [Tentori and Hayes, 2010].

Various kinds of ICT have been shown to be effective for use in treatment and learning. Projects which use computer graphics displays have been recommended for the use of visually cued instructions with autism. Examples include tangible user interfaces for learning social communication skills [Marwecki et al., 2013], and multi-touch tabletops for teaching group collaboration [Piper et al., 2006][Battocchi et al., 2009]. Children with ASD have also shown positive responses to working with robots [Dautenhahn et al., 2002] for practicing imitation and joint attention [Duquette et al., 2007][Robins et al., 2004].

The following sections will describe research done involving digital media in interventions for children with autism.

2.3.1 Robots and Tangible Interaction

The implementation of robots has explored social therapies which teach skills with the integration of a humanoid counterpart, which can the ability to include facial expressions and non-verbal communication. This field of research is of interest to this thesis due to its focus on developing technology-assisted interventions for autism with human mediation, while robots can present a higher level of consistency than human counterparts.

An example of robot-based interventions is the robot Zeno [Chevalier et al., 2017], created for young children with autism. The humanoid robot is used as part of an emotion recognition training program tested in England and Belgrade. The first study consisted of a comparison experiment, in which 66 children participated in emotion recognition training led by the robot, and 66 children participated in emotion recognition training led by an adult. Researchers noted the success of the robot in generating interest and motivation in the intervention. The goal of the project was to explore potential for robot-assisted interventions for autism. In addition, other projects have investigated the role of verbal and non-verbal communication in social interactions with autism, as seen in the AURORA project [Dautenhahn, 1999].

Research on tangible interfaces has also explored the special sensitivities that children with autism display towards sensory stimuli, as research focuses on finding novel and creative ways to implement tactile interfaces. The Interactive Carpet [Zhiglova and Yulia, 2018] was a project developed to explore the potential of a smart textile-based surface in creating social behaviors. The research study focused on how physical properties of the textile surface and its interactive possibilities could promote interaction between a child and their caregiver.

Bendable sound was a project which explores the use of stretchable fabric combined with music therapy [Ortega et al., 2015]. The interface consists of a large lycra fabric mounted on a football goal-shaped structure, behind which is placed a projector and Kinect sensor. Children can explore different shapes projected upon the fabric, which tracks and responds to their movement. Three scenarios were developed for the system, including a starry nebula, planets, and astronauts. In a study with 5-11 year olds, researchers found that the interactive system garnered a greater level of attention from the children, in comparison to a traditional music therapy session with piano.

2.3.2 Virtual Reality

Virtual reality uses real time displays which can represent real or imaginary events and environments. These systems can provide a safe training environment to practice social behaviors, without the distraction of external stimuli [Rizzo and Kim, 2005]. Virtual Reality approaches have proven beneficial for individuals with ASD in planning, problem solving, and management of behavior [Trepagnier, 1999].

Projects for children with ASD have used a variety of virtual reality approaches to teach social skills. Social training can take place through simulation of everyday situations, such as being in a restaurant [Strickland et al., 2007], a birthday party [Ke and Im, 2013], or a bus [Parsons et al., 2006]. Virtual reality and multimedia approaches can also represent magical or imaginary situations to appeal to children's interests, such as a troll forest [Zarin, 2009], an enchanted world [Mora-Guiard et al., 2016], or an alien planet [Giusti et al., 2011][Malinverni et al., 2014]. Social skills training can also create a collaborative environment, where multiple users work together. Examples of collaborative digital projects include solving a puzzle with a partner [Battocchi et al., 2009] and creating an apple orchard narrative [Giusti et al., 2011].

The use of virtual agents as digital peers can be a valuable tool for teaching collaboration and for reducing avoidance mechanisms [Alcorn et al., 2011].

2.3.3 Virtual Environments and Collocated Interaction

In the field of Virtual Environments, research focuses on the positive potential of mediating collaborative environments [Cheng and Ye, 2010], [Millen et al., 2010]. For Dillenbourg [Dillenbourg and Evans, 2011], virtual learning environments create an information environment designed to help in educational processes, and a greater learning potential is achieved when virtual and physical worlds are closely linked. Many projects have utilized virtual environments to mediate social skills training. Projects involving individuals with ASD can be categorized into either single user virtual environments or collaborative virtual environments [Moore et al., 2005], depending on the user capacity and desired functionality of the project.

Practicing socialization in a virtual environment catered towards individuals with ASD can 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.

In the case of multiple users, shared activity surfaces and full-body virtual environments may be designed to collocate users in the same physical space, which allows for direct communication. Alternatively, users may be placed in separate spaces with communication between on-screen avatars. The Island of Ideas [Millen et al., 2012] was a collaborative virtual environment where users accessed a virtual environment from different laptops. iSocial was a three dimensional, multiuser virtual learning environment for the treatment of autism [Stichter et al., 2013]. The project aimed to teach social skills to children with ASD, with the goal to design and develop a virtual environment based on positive social interaction, enabling learning of social competence skills. These projects did not include face-to-face interaction between users.

The COSPATIAL project [Cobb et al., 2010] worked to integrate two approaches, collocated shared active surfaces and collaborative virtual environments, into the classroom environment. This was meant to demonstrate the potential of adding activities for children with autism into educational programs using existing technology. The project used participatory design techniques which involved teachers, experts, typically developing children and children with autism in the design process. The resulting games, called *Talk2U, Block Challenge, Face2Face*, and *No Problem!* were designed to encourage cooperation and collaboration between class members.

The Join-In Suite was developed as part of the COSPATIAL project, and also aimed to demonstrate that collocated intervention through shared activity surfaces can have potential for engaging users [Weiss et al., 2011]. The project consisted of three games called *Raindrops, Save the Alien*, and *The Bridge* game. This project was designed as a multiuser application on a touch table to aid therapists in their use of Cognitive-Behavioral Therapy to increase the social competence of children with high functioning ASD, particularly exploring the use of technology in the Cognitive-Behavioral Therapy model.

Another collocated experience was the Collaborative Puzzle Game by Ben-Sasson et al. [Ben-Sasson et al., 2013], which was based on completing puzzles on a shared-activity surface. The research compared two approaches: free play, where each player could move any puzzle piece whenever they wanted, and enforced collaboration, where both players were told to move the same puzzle piece in unison. Results showed that the enforced collaboration mode led to significantly higher frequencies of positive social interaction and collaborative play. However, the enforced collaboration mode also led to increased challenge and a higher number of uncompleted trials than the free play approach.

Another example of a collocated shared activity surface was the Story Table [Bauminger et al., 2010]. The research found that the use of a multi-user, multi-touch device had positive effect on social interaction between two children with high-functioning autism. SIDES was a cooperative tabletop computer game for social skills development, in which a four-player cooperative tabletop game was developed to practice active listening and perspective-taking [Piper et al., 2006].

The Virtual Errands Task was a virtual environment in which users had to navigate pathways of a building, such as halls and moving upstairs and downstairs [McGeorge et al., 2001]. This project was modified and tested by Rajendran et al. to investigate patterns of multitasking and executive function in individuals with autism [Rajendran et al., 2011]. It was seen that, compared to the control group, individuals with autism displayed a higher level of rigidity and inflexibility through behaviors such as replicating the order of events in the task list and completion of less tasks. This study suggests that difficulties in executive function processes like prospective memory and planning might be associated with multitasking inconsistencies in autism.

2.4 Full-Body Interaction Interventions

As technological advances have allowed for the proliferation of interactive technologies beyond the traditional keyboard and mouse interface, users are not restricted to physical interface elements and can take advantage of more natural and intuitive interactions [Chen, 2012]. Full-body technologies in particular have been seen to assist in learning [Antle et al., 2009], [Howison et al., 2011]. Also, collocated full-body experiences allow for face-to-face collaboration with other users, which has been seen to foster social behavior [Lindley et al., 2008], [Mora-Guiard et al., 2016]. This research shows that full-body interaction systems hold potential as intervention tools for individuals with social disabilities, such as autism.

For individuals with ASD, restricted and repetitive behaviors, interests and activities can lead to motor skill impairments [MacDonald et al., 2014], passivity [Gabriels et al., 2005], and sensitivity to sensory stimuli leading to over-reaction or under-reaction to stimulation [Lane et al., 2010]. Working with full-body interaction not only allows for users with ASD to practice sensorimotor skills, but also incorporates a larger range of communication, such as non-verbal communication, as systems detect expression through body language and proxemics. These non-verbal forms of communication are not usually accounted taken into account in interactive devices such as desktop computers, smartphones, and tablets.

We have chosen full-body interaction as a medium for creating experiences where children with ASD can put into practice social skills with other peers based on its potential for natural and uninhibited interaction between collocated users, in comparison to single-user interactive devices, which offer no direct contact with other human beings and present a risk of forming dependencies due to their ubiquitous presence.

Full-body interaction can be understood as "using the movements and the actions performed in the physical space by the body of the user as mediators of the interactive experience" [Malinverni and Pares, 2014]. In the field of embodied interaction, few research projects have explored the use of full-body interaction media for the development of experiences that promote collaboration. Unlike traditional interactive media, this medium can offer collocated experiences aimed at promoting collaboration by including the use of non-verbal body language and gestures, which have been shown to aid in thinking and in understanding others [Rambusch and Ziemke, 2005]. Also, collocating multiple users in the same physical space allows for a fluidity of awareness of other's actions [Yuill and Rogers, 2012], creating a natural dynamic of collaboration and allowing for implicit and immediate understanding between users and ecological validity as it is the most similar situation to real life social interaction. In this case the interactive experience becomes the physical and semantic context while it can still mediate the experience in subtle ways.

The full-body interaction paradigm has proved successful in fostering user's engagement [Bianchi-Berthouze et al., 2007]. This media has also proved to be effective in encouraging socialization behaviors [Lindley et al., 2008], making it suitable for the development of collaborative activities where users can practice social skills.

2.4.1 Embodied Cognition

Traditional Cartesian views of cognition regard the mind and the body as two separate entities, where the mind is the center of all cognitive activity and the body is a support for it. Embodied Cognition theories challenge this understanding, holding that the functionality of the mind must be understood in unison with its connection to the body [Dourish, 2001], [Wilson, 2002]. In the lens of embodied cognition, human knowledge is not only something abstract but is also linked to our active engagement with the world through our body [Borghi and Cimatti, 2010]. With the formation of a unique viewpoint, each individual's cognition is influenced by and connected with their corresponding bodily dynamics and social context [Roussos et al., 1999].

The theoretical basis for full-body interaction may be understood as a dynamic relationship between cognitive processes and the subjective human experience that we construct by living and moving within the world. *Embodied cognition* theories hold that cognition is mediated by the human body and its place within the surroundings [Borghi and Cimatti, 2010]. It is this relation between body and space which defines our human cognition, allowing us to make sense of the world through a contextual construction, being directly generated by our previously developed perceptions and experiences. Hence, when analysing our learning processes, embodied cognition states that our knowledge is not just an abstract construct. This perspective, known as situated learning, sets learning as a social activity between humans as constructors of knowledge [Rambusch and Ziemke, 2005]. Therefore, meaning is created as we collaboratively interact with others and the world around us [Fuchs and de Jaegher, 2009].

Lakoff and Johnson argue that the mind is inherently embodied, and reason comes from the experiences we undertake in our bodily form [Lakoff and Johnson, 1999]. The commonalities of thought and reason among humans descend from the similarities in our bodies and habitats. This philosophy highlights the crucial role of the body in our process of understanding interactions with the world, which melts into every aspect of our language constructs. They therefore argue that all the metophors we use for describing abstract concepts or situations are rooted in our physical experience of the world.

Navigating through physical environments allows 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 movements and without the added weight of sensing devices [Grandhi et al., 2011], [Nielsen et al., 2004].

2.4.2 Embodied Interaction

In the field of human-computer interaction, embodied interaction takes the human as an active participant in a particular setting [Dourish, 2001], not just as a presence but as an embodied actor with a unique understanding and influence [Harrison et al., 2007].

Embodied interaction has unique properties when compared to other media paradigms, as users can take part in activities through direct physical manipulation of virtual content along with other users [Antle, 2013], [Dillenbourg and Evans, 2011].

This concept of embodied interaction also aims for direct manipulation of the virtual environment by collaborative user groups [Dillenbourg and Evans, 2011][Antle, 2013]. In addition, as emotion is seen to be connected to cognition and understanding of information [Harrison et al., 2007], full-body interactive environments based on embodied interaction and user states can be advantageous for learning of concepts [Goldin-Meadow, 2011]. This was shown in an experiment by Benson and Uzgaris, where babies who were allowed to crawl through an environment found hidden objects easier than babies who had been carried through [Benson and Užgiris, 1985]. This shows how active first person exploration of an environment leads to mental model construction [Bartoli et al., 2013].

Also, the framework of Embodied Facilitation describes how the layout of material objects and space relates to group behavior [Hornecker and Buur, 2006]. This theme is important when designing play experiences, as providing feedback to physical activity can be implemented in group settings to stimulate physical play [Bekker and Sturm, 2009].

2.4.3 Full-body interaction technologies for Autism

Virtual environments allow for customized configurations of senses, movement, and communication in the virtual setting [Cobb et al., 2010]. As individuals with ASD commonly have difficulties with motor skills [MacDonald et al., 2014], full-body virtual environments can allow a freedom of movement beyond the traditional mouse and screen setup [Chen, 2012]. Full-body virtual environments place the body as the center of focus, as the user controls the systems with body movements [Pares et al., 2005], incorporating the use of gestures and non-verbal language which are key to interpersonal communication. Large scale full-body interactive environments also allow for physical exploration and face to face interaction between users [Mora-Guiard et al., 2016].

In the research of full-body interaction systems for children with ASD, various projects have aimed to implement embodied interaction for the purposes of motor movement therapy, play therapy, and socialization via collocated interaction.

ReacTickles was a playful exploratory system for children with ASD where children could easily explore different "magical" interactions without previous knowledge of the technology [Keay-Bright, 2007]. ReacTickles aimed to explore the possibilities of virtual environments to foster opportunities for expression and to foster immersion in the learning process during playful intervention.

Another full-body interactive project for acquiring social skills was The ECHOES Project [Porayska-Pomsta et al., 2018]. 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 avatar for mediating interaction named Andy, which used a computer vision system to interact with the children and understood children's focus towards the virtual objects for joint attention.

The Pictogram Room was a Microsoft Kinect based project which used an augmented reality approach to superpose pictograms to the body gesticulation of children for the purpose of clearly communicating the relation between icons and body, to support imitation therapy for social behavior learning [Casas et al., 2012]. Bhattacharya et al. presented research using Microsoft Kinect in a classroom setting to promote engagement with peers and social behaviors in children with ASD [Bhattacharya et al., 2015]. In addition, the European project M4ALL focused on the development of motion-based adaptable playful learning experiences for children with motor and mental disabilities. This project, which included the videogame Pico's Adventure, explored the use of Kinect based technologies for learning and practicing social skills in children with autism [Malinverni et al., 2014].

2.5 Play and games

As children, play provides a safe space for developing the imagination and exploring creative narratives. According to Wiederk, play is a vital part of childhood, where children can share and explore thoughts and feelings [Wieder and Greenspan, 2003]. It is a time when children can distance themselves from real life enough to think in abstract terms, assigning symbolic meanings to everyday items. In the case of children with neurodevelopmental conditions like autism, the imaginative world can expand regardless of the boundaries placed on physical and sensory means. In fact, research has shown the potential of play-based therapies in the development of social and communication behaviors in children with autism [Casenhiser et al., 2013].

What are the defining characteristics of play? Imagine two children; one is spinning in circles for the sake of enjoying the playful sensation of the activity, and the other is engaged in a strategic game of chess, carefully planning her next move. Which of these activities constitutes as play?

According to Caillois, play can be built within or around the boundaries of game rules, or objects, while retaining a certain degree of freedom for creative construction [Caillois and Barash, 1961]. In the previous example, both of these children's activities might be considered as play, even taking into account the different nature of the activities. Unstructured expressions such as spinning in a circle are considered freeplay (*paidia*) and rule based interactions with challenge and competition, such as a carefully plotted game of chess, are considered games (*ludus*).

The degree of interpretation given to players is mediated by whether the play arrangement is open-ended or goal oriented. Open-ended play refrains from strict structural elements, and allows children to create their own rules for play [Bekker et al., 2008]. For example, when given a plastic ball, children will begin to propose and negotiate play dynamics, all the while exploring the properties of the play object. In this process, creativity is drawn from each player's subjective frame of reference, mixing them with the experience and suggestions of other players [Morrison et al., 2011]. Open-ended play exists upon a spectrum, with free play (based on improvisation and spontaneity) on one end, and games (with fixed rules and structures) on the other end.

Research is needed to understand the effects of rules and goals on fostering social collaborations in play. In an experiment by Dewey, Lord, and Magill, it was found that rule-based games were considered the most fun, and yielded the most complex interactions [Dewey et al., 1988]. However, when children were given glowing play balls in an experiment by Bekker, it was observed that children liked playing more in free-play sessions than in preset game sessions [Bekker et al., 2008]. In both experiments, it was found that more intricate social interaction resulted from pre-set rule conditions; however, no quantitative measurements were given on the number of social acts in each scenario. It is still unclear whether more advanced or more frequent social behaviors lead to effective relationship building.

What must we consider when building play experiences? In order to create an enjoyable, and more importantly, engaging, play experience, certain factors may need to be taken into account. In the realm of computer game development, there must exist a balance between sense of control, the chance to create strategies, and the search for new information [Neal, 1990]. Maintaining player engagement means the game play must also uphold a certain degree of challenge. These challenges are supported by clear goals and attainable goals which the player must work towards during the course of play [Myers, 1990]. When the challenge of a game is met with feelings of enjoyment, the player enters the moment of "flow", which is considered a highly concentrated and fulfilling state [Csikszentmihalyi, 1996], [Goh et al., 2008]. Moreover, players can maintain motivation through feedback such as positive or negative reinforcements, which can be a valuable tool for children in the process of developing new skills [Malone, 1982].

The Magic Circle

The concept of the "Magic Circle" originates from the phenomenon that begins when players agree to participate in a play scenario. The term was originally used by Huizinga as a functional playground where special rules prevail, generated in real-time through interpersonal processes [Huizinga, 2007]. The term has since been adopted to describe the real or imaginary "frame" [Salen and Zimmerman, 2003] which separates the play space from the real world. As interactive experiences have their own set of rules and possibilities which are separate from ordinary life, these settings have the potential to create an alternate temporary world where relationships between players and game objects, or otherwise meaningless configurations such as the the arrangement of pieces on a game board, can have increased significance and influence over events that unfold. To create this magic circle, users may either enter into a pre-existing circle of rules as defined by game designers, create their own system of rules, or create these based on the affordances given by interactions and objects in an open-ended setting. Just like lighting a flashlight in a cave to flesh out bends in the path, this exploration yields understanding which will serve as their bearings and guide them through decisions made in the game world. When entering into a predefined scenario without given instructions, users begin exploring and toying around with objects present in order to discover the possibilities which lie in their new environment, eventually using observations to build a set of rules.

In the case of virtual environments for autism, it should be understood that the system presents an interactive scenario for play and learning with its own rules and boundaries, while retaining the intention that interactions learned wherein can be generalized to real life situations.

Curiosity and the Invitation to Play

The idea of gameplay as a multiple stage model beginning with a system's invitation to engage with the user was originally presented by Polaine [Polaine, 2010]. This model was later referred to by de Valk, et al. as a three phase model of invitation, exploration, and immersion [de Valk et al., 2015]. The significance of this three phase model is to demonstrate that gameplay can be a process with multiple stages. One important aspect from both Polaine and de Valk's models is the placement of curiosity as the driver of interest in the initial stage of play. Users have not yet begun interaction during this *invitation* stage but are on the cusp on entering the gameplay scenario, perhaps watching others play or observing a hint of interactivity in the play setting. When users begin to experiment with a system's possibilities, they begin the *exploration* stage, where they try to determine how things work and discover the various opportunities or activities that are within their reach. From this, they begin to piece together possibilities and create their own challenges in an open-ended experience. This creation of rules and play dynamics by users constitutes the *immersion* phase.

The play activity can be fueled by internal motivation, which is fostered by players developing their own goals, using exploration as a means to foment this development of understanding and expectations. If a goal has been defined by designers, users begin to combine their new knowledge to reach the known goal.

Proxemics

Proxemics is defined as the interpersonal distance between people [Mueller and Isbister, 2014]. Interaction styles, behavior and communication are elaborated in correspondence with this distance between bodies. In the research done on interpersonal distance, proxemics zones are commonly divided into four zones: intimate, personal, social, and public [Hall, 1969]. Although cultural backgrounds define various interpretations of zone boundaries, the zones are generally understood with respect to their appropriate social interactions. The public distance is used to address large audiences, with a distance of more than 12 feet. The social zone is used for interactions among acquaintances, within 4-12 feet of the speaker. The personal zone is within 1.5-3 feet and is for interactions between friends or coworkers. The intimate zone is reserved for private interactions, such as whispering, and is within 0-18 inches of the speaker.

Although the boundaries between zones are invisible, humans have a subconscious sense of passing through various interpersonal zones [Mueller and Isbister, 2014]. In a project by Vogel, an interactive display mediated interactions with agents based on the closeness of the user to the screen. This project was designed to examine the effect of physical distance on interpersonal relationships [Vogel and Balakrishnan, 2004]. Thus, proxemics can be used as a tool to foster interactions between players during a game or collaborative activity. Nonetheless, research must be done to understand how proxemics can be implemented in the design of interactive systems to foster socialization and collaboration, which will be discussed in Chapter 5.

Designing for special needs

In the design of interfaces for children with special needs, several patterns have emerged as indicators of inclusive design. For example, involving children has been held as an important aspect of the design process, as their interests, abilities and values differ greatly from adults [Read and MacFarlane, 2006]. As the experience and perspective of children with special needs includes many differences from the typically developing population, this inclusion of children's voices can be done through participatory design studies [Malinverni et al., 2016b]. Also, using common, recognizable objects is a way to create intuitive interaction [Morrison et al., 2011].

For children with ASD, imitation is seen as an important function in the development of social skills [Ingersoll, 2008]. Also, activity based learning with peers is preferred by children rather than direct instruction [Bottema-Beutel et al., 2015]. Constraints and structure in the system work to the benefit of children with ASD [Giusti et al., 2011], along with task consistency and the gradual introduction of new elements [Davis et al., 2010]. Finally, sensory reinforcements have been shown to motivate learning in young children with ASD [Rincover, 1978].

2.6 Antecedents of the group's research

The work done in this thesis will be informed by relevant studies conducted previously by the Full-body Interaction Lab of the Cognitive Media Technologies research group at University Pompeu Fabra. The work of this research lab builds upon media formats which have been created for use in intervention with children with ASD.

The project MEDIATE, a Multisensory Environment Design for an Interface between Autistic and Typical Expressiveness, was first tested in 2004 as an interactive environment to allow for creative exploration in children with ASD [Pares et al., 2005]. The system included tactile, visual, and auditory stimuli in a 6-walled space where children could experiment with the creation of various audiovisual feedback displays. The environment utilized sensory interactive elements such as a vibro-tactile feedback wall, surround sound audio and an interactive floor. This was an early version of an interactive environment which was created specifically for children with low-functioning ASD, taking into account their needs and preferences, so that they could feel a sense of control over their surroundings. As the environment was designed for children with autism who did not possess language skills, the system was designed to embody a dialogue between the children and the environment through creative exploration and sensory interaction via the use of gestures.

The project SIIMTA, which stands for "Real-Time Full-Body Interaction System and Music Therapy for people with disabilities or disorders such as Autism" in Catalan, was developed in 2009 and aimed to explore the potential of full-body interaction technologies with music therapy for children with low-functioning ASD. The system consisted of a first person interactive system where users could interact with a colored particle system through gesture-based interaction. The system responded to user movements with sensory stimuli in the form of corresponding musical notes. While interacting, children with autism were able to put into practice gross motor skills. The goal of the project was to combine natural body movements with musical elements to improve user engagement during therapy sessions.

Figure 2.1: Lightpools was created to foster socialization among general audiences.

The project Pico's Adventure was a front-facing, third-person Kinect-based system designed for young children with high-functioning ASD, where users could view their own silhouette as they interacted with a virtual agent onscreen [Malinverni et al., 2016a]. In Pico's Adventure, the virtual agent led the child with ASD through a series of activities for practicing social initiation skills. The game consisted of four levels where children gradually increased collaborative play, first with their parents and later with a child peer with autism. The system was designed through a series of participatory design workshops which aimed to elicit the help of children with autism in the creation of a play-based game for therapy. Goals for the system were designed in collaboration with the Hospital Sant Joan de Déu and were based loosely upon the methodologies of Applied Behavioral Analysis (ABA). The system had positive results for encouraging play and social behaviors. Nevertheless, the orientation of players side-by-side facing the screen led to a search for a system which would encourage more face-to-face conversation.

The project Lightpools or *Ball del Fanalet* was an interactive art installation developed in 1994 with the primary goal of fostering socialization among general audiences [Hoberman et al., 1999]. The project consisted of a large scale arena which was circular in form, created to prevent potential isolation of users in corners and guide participants back to the middle of the physical and virtual environment. The system presented a display projected from above. Users could interact with randomly generated proto-objects through the use of handheld lanterns (see Figure 2.1). These lanterns were designed in the style of Catalan fanalets, a culturally symbolic artifact used in traditional dances, and each contained an ultrasound position sensor. Although the system was designed for general audiences, in an informal play setting, the system was tested with children with autism and was found to spark social initiation behaviors. Parts of the Lightpools concept were adapted to form the basis of further research projects for autism, specifically the use of handheld culturally significant pointers and a large scale circular arena with a basis of exploratory and open-ended play.

CHAPTER 3

Methods

3.1 Introduction to this chapter

In this research, we have explored the possibilities of fostering situations where children with autism can practice social interaction, selecting full-body interaction media as it allows users to communicate in the context of a shared physical space. Within this context, three projects were developed and tested for this thesis (see Figure 3.1). The first project, called Lands of Fog, was tested through a feasibility study in the form of controlled laboratory trials to evaluate the potential of the technology to scaffold socialization, collaboration, and motivation between children with autism and a typically developing peer. For the second project, Lands of Fog 2, we moved one step further and carried out a formalized comparison study to evaluate an expanded version of the system against traditional therapy practices within a repeated measures experimental design. For the third project, called GenPlay, we developed a compact system and ran a feasibility study within a classroom setting to test the effects of the technology within an ecologically valid context.

Although varied in form and practice, all of the projects included in this thesis revolved around the same basic premise: to foster social and collaborative behaviors in children with autism. As a general view, we developed

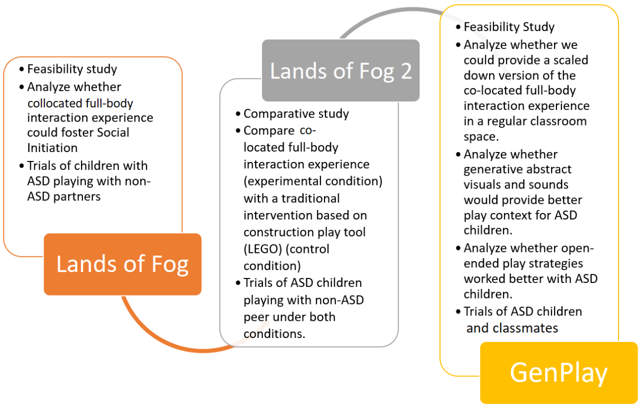


Figure 3.1: Purpose of projects developed

the technology to be fit for an experimental testing, beginning with an inclusive design process. Each of the projects embraced an interaction-driven design philosophy, as this thesis was designed to build upon previous projects working within the scope of full-body interaction for autism. Therefore, although each project differed slightly, this section will describe the general process of how we carried out the **design, development, testing**, and **evaluation** of the projects included in this thesis, taking into account the full-body nature of the research line (see Table 3.1).

3.2 Design methods

3.2.1 Multidisciplinary team members

After selecting the platform and identifying the interactions possible, we set to work on the project ideation and design process. We embraced a multidisciplinary approach, aiming to include professionals and students with a variety of voices and backgrounds. For the projects discussed in this thesis, we have sought the involvement of individuals trained in interaction design,

Table 3.1: Methods followed for each project

	Design				Development	Testing		Evaluation
	Multidisciplinary team members	Professional feedback	Sprint design sessions	Participatory design	Iterative prototyping	Ethical approval	Experimental procedure	Multimodal data
Lands of Fog	X	X		X		X	X	X
Lands of Fog 2	X	X				X	X	X
GenPlay	X	X	X	X	X	X	X	X

sound design, visual design, and photographic design. We involved technicians trained in computer engineering, physiological sensing, and worked with students completing their bachelor degree in Audiovisual Engineering and master students in the Cognitive Systems and Interactive Media at University Pompeu Fabra.

3.2.2 Eliciting professional feedback

Contextual analysis was carried out by interviewing professionals involved in the autism community, including teachers, parents, a school director, and a speech pathologist (see Figure 3.2). The goals of these interviews was to understand gaps in the current social integration of children with autism in mainstream school settings. Contacts included former university colleagues who had gone into the fields of interaction design or autism research, and contacts who were working in the psychology field. Interviews took place over Skype, at the university, hospital, and schools, and helped to gain an idea of the broader context of the project.

The projects in this thesis operated under a working collaboration with the professionals at the Hospital Sant Joan de Déu in Barcelona, which has a special unit dedicated to diagnosis and research on autism. Their help included serving as a guide in deciding therapeutic goals and providing references on the current state of autism integration in education centers in Catalonia.

Figure 3.2: Interviews with a school director, parents, speech therapist and psychologist formed part of the contextual inquiry phase.

With the help of the hospital, we were able to contract project psychologists who participated in the projects from the initial ideation phases through serving as an initial contact for the participants, assisting in experiments, and helping to develop an evaluation procedure. As the psychologists split hours between private practice and working on our projects, they provided a first hand account into working with the children that we as university researchers did not possess. It is not only recommended to work with professionals due to the sensitive nature of these projects, but we also saw it as essential in creating a line of projects which would adapt to the criteria of the current educational context in Catalonia.

With the help of the psychologists, we were able to conduct interviews with parents and caregivers of children with autism, who shed light on the challenges that they encountered with their children. These structured interviews helped to adjust the project goals to create something that would realistically face the needs proposed from these children and their families.

Finally, we were able to create a working agreement with a special school for children with language conditions in Barcelona, called the Escola Fasià. Visiting the school and speaking with teachers, the headmaster, and carrying out guided activities with the children was helpful in adjusting the project design to fit the capabilities and practices of the children who were attending school. With the guidance of the school personnel and detailed talks describing challenges the children faced in school contexts, we were able to create project goals which aligned with the teachers' vision for integrating children into mainstream school settings. Additionally, sitting in on the class sessions, whether as passive observers or actively participating in design-focused activities with the children, helped to understand some of the practices which are used in communicating with the children during a typical school day.

3.2.3 Sprint design sessions

To bring these individuals together upon a common basis, in the project GenPlay we carried out a rapid design and prototyping practice called a Sprint, which has gained recognition in the startup culture as a way to produce many possible iterations and answer important project questions during a condensed working period. We chose to follow the Google Design Sprint process [Knapp et al., 2016], which takes place over five days, although we spread it out over the course of two weeks to accommodate variations in schedule for different team members, many of whom were also completing full-time degree work (see Figure 3.3).

To begin the Sprint, all of the team members were sent detailed information about the upcoming week's activities and asked to research existing ideas that aligned with the present project proposal. On the first day of the design sprint, a main project goal was decided upon by all team members, and a map was drawn of the potential users and how they would interact with the system. We chose a target area on the map that we wanted to address with that Sprint session, usually involving a set group of users (i.e. practitioners or teachers) and their direct contact with the system.

Figure 3.3: Sprint sessions were held to develop prototyping proposals and coordinate team members under a cohesive vision.

During the Sprint weeks, each of the project team members were asked to find a resource that could lend information to the project. This helped team members integrate into the team by contributing resources from their personal network, as well as opening up a professional network involved with the project. Over the next days, we alternated between interviewing professionals and stakeholders and creating design iteration proposals. Design iterations were seen as simplified variations on how the system would address the project goals. Each person was asked to create various design proposals based on their vision of the project, which they would later 'pitch' to the team. The team then agreed on their favorite designs and combined them to create a workable vision. The Sprint week concluded with a low fidelity prototype of the system which was tested with volunteer users to gather feedback and impressions.

The Sprint method was selected to bridge the gap between interaction design practices in industry and academic settings. We also decided to follow the Sprint method in order to condense the design phase to a length of time conducive to the academic term, as there were several bachelor and master students involved in the projects. The Sprint sessions were not only meant to create results in terms of a working prototype, but also aimed to create group cohesion and common thinking. Although the sessions consisted of long hours, several team members commented that these weeks were their favorite part of involvement in the project.

3.2.4 Participatory Design

While working on the preliminary design phases of the projects, we adopted a participatory design methodology to incorporate children's voices into the full-body interactive systems. We saw this practice as an especially important part of creating systems adapted to their special situation. This is partly because children and adults have an inherently different view of the world, influenced by their interests and capabilities [Malinverni and Pares, 2014]. However, the experience of a child with autism differs greatly in respect to typically developing children and adults, not only with regard to their needs and interests, but also in their sensory intake and communication capabilities. We viewed that asking children with autism to participate in the design process constituted a vital part of creating a system which would empower them not only as players but also as creators of their own unique world.

Although the roles of children differed between projects, their participation was present in some form throughout the design of all projects mentioned in this thesis. During the first project, a group of four children with autism participated in workshops with the designers to brainstorm ideas for the content, structure, and mechanics of the game. The children's ideas were translated to drawings by a graphic designer in the team, which were later developed into three dimensional models and integrated into the game design.

Participatory design techniques did not play a major role in the Lands of Fog 2 project, as changes were primarily proposed and decided based on observations collected during the first phase of the project. To determine these changes, we reviewed videos of all the experimental trials and the notes written during the experimental process, relating to possible improvements in the system. Also, we held a brainstorm session with the children involved in classroom trials with the project, and they shared their ideas on possible improvements to the system. Finally, we asked the children to play the game and "think aloud" about their actions in the game, which helped us to understand their perspectives. Observations collected from these exercises formed the basis of changes implemented in the Lands of Fog 2 project.

For the GenPlay project, the children worked with the designers in an informant role. This role of children in the participatory design process differed greatly from the first two projects. As the premise of the GenPlay project was already set prior to the design phase, in that it would be an abstract floor-projected environment based on generative audiovisual displays, we were more interested in the degree to which children with autism were comfortable with abstract elements. We also wanted to involve them in developing a set of embodied interactions which would be natural for them. For this project, a series of workshops was carried out with the children in their classroom and playground environments, to try to understand the types of interactions that came natural for them and that could be configured into playing with a generative particle system.

3.3 Development methods

3.3.1 Iterative prototyping and usability trials

After gathering the parameters of the project and working with the team to create a unified vision, a collection of design iterations was agreed upon and subsequently developed. Each design iteration approached the system vision with slightly different parameters, while still meeting the overall goals of the project. For example, in one project we decided to use a generative particle system based on the idea of a flowing river with which children could interact. From there, we discussed all of the actions possible with a river: i.e. standing in the flow and watching the water change directions to move around the user, throwing water particles to others nearby, kicking and stomping on the water puddles, etc. Then we worked to design a separate interactive scenario which addressed each of these themes, and explored versions with different sizes, velocities, and colors of the particles.

When we had compiled a set of basic iterations that addressed the project themes, we conducted usability trials to see if the system clearly communicated the design affordances to the children. In the first project, this phase was done with a Wizard of Oz method, where placeholders were projected upon the floor and users moved through the interactions as if they were playing inside a developed system. In the later projects, we created low fidelity prototypes with the Unity game engine and a Kinect camera which could to track the children's movements. For the usability trials, we invited typically developing and autistic children to come to our interactive space either with their parents, with their school, or as part of a weekend technology workshop. As they played, we asked them to take part in a "thinking aloud" exercise where they navigated through the game and expressed their thoughts and narrated their actions. Afterwards we asked several questions to get an idea of their impressions. One example of a questions was, "What do you think was the purpose of the game?" After, we asked the children to take part in various design activities, such as creating their own redesign of the game using clay figures and acting it out with a partner.

After each usability trial, we discussed the results and eliminated the least successful iterations and further developed the iterations which appealed most or created the most conversation between the children.

3.4 Testing methods

3.4.1 Ethical approval

Before testing the system and collecting data with children, we completed a process of ethical validation with both the University Pompeu Fabra and the Hospital Sant Joan de Déu ethics committees. Each of the evaluation committees reviewed the proposed experimental procedures and made recommendations that would bring the project within their acceptable ethical standards. This approval process included not only drafting an experimental procedure, but also submitting the consent forms and explaining in detail the data protection measures. Because we were working with children with special needs, all of the participant data was anonymized and kept under password protection on a secure private server of the university.

3.4.2 Developing an experimental procedure

When we decided on a final design and developed it to completion, we then created an experimental procedure that addressed each of the project goals. This process began with testing the experimental procedure through a set of pilot trials. These trials were meant to ensure that the system ran smoothly, that the system and data collection configurations were adequate, and also to leave a window for creating final changes to the system. One important finding in the Lands of Fog pilot trials included discovering that the time allotted for trials was too long and the children were becoming disengaged towards the end of the activity. In another pilot trial, we saw that the data collection through oral interviews was not ideal for children with communication difficulties, and this motivated us to transfer the survey part of the experiment to an iPad format.

In working with children with autism, we saw it necessary to enlist the help of a psychologist who would be on site during each of the trials. The psychologists played a passive role through the trials, as the goal was not for them to guide the interaction but rather to reassure the children and parents in case of any unexpected situations. They also helped to review the trials afterwards with the project team, watched for anxiety indicators while the children were playing, and interpreted the special nuances of communication in children with autism such as echolalia and idiosyncratic language. This brought an additional level of meaning to the project and helped us to understand the possibilities for how the system could be implemented in a therapy setting.

3.5 Evaluation methods

3.5.1 Multimodal data analysis

Each of the projects collected data related to the individual project's goals, and included multimodal analysis through qualitative and/or quantitative measures. Previous project have relied upon written questionnaires or interviews to gauge the success of technological interventions. However, given that children with autism present difficulties in verbal expression, we decided to use multimodal data analysis to gather precise data that would help us to understand the experiences of the children that they were not able to communicate verbally. This allowed us to gather data not just about the children's perspectives, but also about the ways they interacted with the system and simultaneously with their peers. Data collection included standardized questionnaires, video coding of session recordings, system log files, and physiological data.

As our primary aim included fostering social and collaborative behaviors in the children, we relied heavily upon video recording the sessions for later coding target behaviors in all three projects. Each of the systems was also configured to record a log file of significant actions and player position, which was useful to have a moment-by-moment record of player interactions with the system. Other data recording that we used included self-report surveys to the children, or pre- and post-session surveys to the parents/teachers using Likert scales to identify measures such as flexibility while playing. For the Lands of Fog 2 project, physiological data was implemented as a way to better understand changes in the children's active state during moments of socializing with a peer in the system. More detailed information on data collection and evaluation methods can be found in Chapter 6.

Chapter 4

Developed Projects and Results

4.1 Introduction to this chapter

This chapter will focus on the design of three interactive systems which form the basis for this thesis. Each project will be presented first in terms of motivation, background, and notable points from the design process that we followed. Next, the most important findings from testing the system will be presented, arising from the design of the system.

All of the systems were developed for children with high-functioning autism to play with typically developing peers or classmates. The first design case is the initial Lands of Fog system, developed for the IN-AUTIS-TIC project (2013-2015). The next section will discuss an updated version of the Lands of Fog system which was created for the ASC-MEOR project (2017-2019), which included improvements to the design, based on results from the initial study. These projects formed the inspiration for the project GenPlay (2017-2019), which was created as a classroom adaptive system for collaborative play in autism.

4.2 Design Study 1: Lands of Fog

Parts taken from the article *Lands of Fog: Helping Children with Autism in Social Interaction through a Full-Body Interactive Experience* [Mora-Guiard et al., 2016] and *Sparking social initiation behaviors in children with Autism through Full-body Interaction* [Mora-Guiard et al., 2017]

Lands of Fog is a full-body interaction system designed to improve behavioral and cognitive skills in children with HFASD. The collaborative virtual environment was designed to scaffold social interaction by creating scenarios which would enable children with ASD to work together with typically developing children towards a common goal.

4.2.1 Motivation

Lands of Fog was created within the project IN-AUTIS-TIC: Integration of Children with Autism into Society using ICT, funded by the RecerCaixa 2013 grants program. The project was developed 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 from Hospital Sant Joan de Déu (Barcelona).

The primary goal of the 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 developing companion. Given the affinity that children with ASD show towards digital media, the project aimed to explore the potential of different technologies for developing systems for therapy and intervention, such as full-body interactive technologies. 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].

The goal of promoting collaboration is threefold. On the one hand, collaboration requires different types of communication for the users to agree on their common goals and the strategies to attain them. This makes them naturally practice social communication abilities. On the other hand, promoting collaboration could motivate users to see their peers as valuable play partners. Given the problems of social integration and maintaining social relationships in children with ASD, creating scenarios where users see each other as valuable partners could help to develop and maintain friendship.

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 video games and would therefore meet children's expectations.

4.2.2 Background

Lands of Fog was originally inspired by a full-body interaction artistic installation called "El Ball del Fanalet" or "Lightpools" [Hoberman et al., 1999]. This project explored the social potential of full-body interaction technologies. Users explored virtual content through the use of hand-held pointers shaped as paper lanterns. While exploring, users could feed basic objects to obtain more complex abstract objects, which later could be trained to perform simple dances.

In 2001, an informal play session of a group of ASD children with Lightpools showed the potential of the installation to spark social initiation behaviors in HFASD children. The original artistic approach of fostering social interaction in typical users seemed to also be useful for children with ASD. To take advantage of selected formal properties of Lightpools, a new experience was conceived for children with ASD. Lands of Fog became this 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.

Design

From the previously defined goals for the research, 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, and 3) positive social interaction attitudes would be observed between the child with ASD and the typically developing child during the sharing of the experience.

The design strategies presented were aimed at achieving the three hypotheses; therefore, the description of the design process will be organized according to these objectives. Each design strategy will be described by framing it in relation to the previous experience with Lightpools, background knowledge of interaction design, the participatory design workshops and related technical considerations.

Participatory design When developing technologies for individuals with special needs, previous research has highlighted the importance of involving them as informants in 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* which involves people of the target population in the design of the technology [Ehn, 1990]. For the definition of the narrative and interaction content, five participatory design sessions were conducted where four children with HFASD gave their input and ideas. These participatory design sessions yielded insights into the characters and overarching concepts used in the final game.

4.2.3 Selecting the medium

As the interaction paradigm that we would use was predetermined to be full-body interaction, we then decided on the platform to use for the project. When deciding on this platform, we took into account the possible configurations of users with that paradigm and the breadth of bodily gestures to incorporate. We also discussed whether the users would interact with the system via a physical device which acts as a pointer, or whether the interaction would take place through their own bodily movements. This decision determined the system components that would be used, based upon the pre-existing project requirements. For example, in the first project to be discussed, one goal was to foster serendipitous contact between users through open-ended exploration. For this goal, we decided that mapping the user movement on a two dimensional coordinate system would be sufficient, so we used a simple color tracking system to trigger system reactions when the children came into close contact.

The physical interface The physical configuration of the experience was been designed around a 6 meter in diameter circular projection (see Figure 4.1). This was based on the experience of Lightpools which also used this configuration. Specifically, the circular projection encourages movement through the lack of corners, continuously directing players towards the main playing area. Additionally, the diameter of 6 meters allows sufficient area for free roaming of the children within the space. This allows them to easily adopt exploratory attitudes as they wander through the physical space. This large physical size allows each user to have his own space and not feel pressed to interact with the other. At the same time it encourages serendipitous encounters of the two children providing opportunities for them to start interaction; either physically, or through the events occurring in the virtual environment.

From the experience with Lightpools, it was decided that children would have a pointer in their hand to interact with the world. The pointer was used technically for tracking users in the interactive space, but also worked as a cognitive offloader for the users. The pointer helped children with ASD to focus on the relevant virtual elements, helping them 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

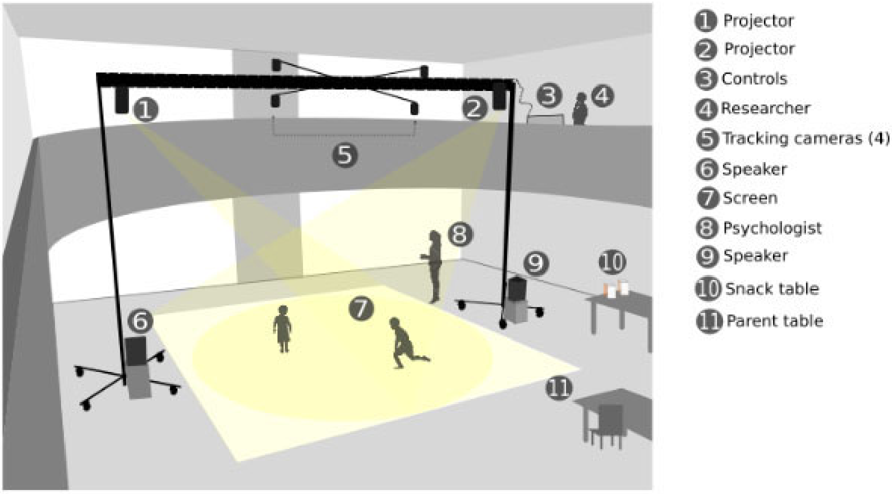


Figure 4.1: The Lands of Fog system consisted of a 6 meter in diameter floor projected virtual environment.

mental mapping between the physical and virtual world.

4.2.4 Design Strategies

Engaging the user

As autism is characterized by limited interests and repetitive behaviors, one of the objectives of the project was to design an installation that would engage players with ASD to play. This initial step is key when designing tools for assisting therapy or intervention, as it is important to keep users engaged to maximize the desired outcome of the sessions.

A world covered by fog The concept of the virtual world was designed in collaboration with the children with ASD during the participatory design sessions. It was designed to be a unique place where different kinds of biomes met and where strange and unique insects and creatures lived. The world was based on four different environments that coalesced in a unique space: 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.

The users cannot see all of the virtual environment at once. This is similar to how Lightpools worked. The idea was meant to encourage exploration, so users would be motivated to explore the space by physically moving around. Hence, we thought the virtual environment 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 world below. As the user moves in space, the hole follows him and he can start to understand the structure of the virtual environment. Having a rich world covered by a layer of fog was meant to motivate user engagement and exploration by increasing the interest to discover novel elements which 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 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 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. Nonetheless, these flocks occasionally fly above the fog to show that some virtual objects exist in the virtual environment. During the participatory design 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 objectives and transitioning to more complex objectives 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. and Jordan [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.

Figure 4.2: Children could merge creatures by collaborating with a partner, to explore various possibilities.

During two participatory design sessions children gave ideas regarding the different creatures 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 (see Figure 4.2). The participatory design 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 four different versions for each of 14 different creatures, 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 typically developing children and in children with ASD).

A total of 16 different objects could be found in the environment. When transformed, unique animations and sound effects 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. The virtual environment consisted of four different biomes with corresponding creatures and props: ice, lava, forest, and ruins (see Figure 4.3).

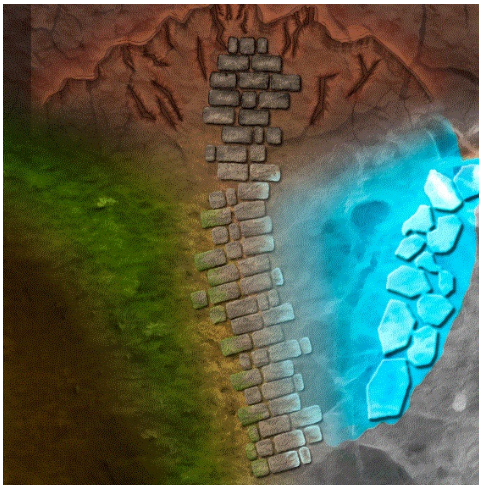


Figure 4.3: Four biomes were present in the environment: ice, lava, forest, and ruins.

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 developing children to see children with ASD as valuable play partners, encouraging social integration.

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 was meant to prevent children from trying to compare their numbers of fireflies.

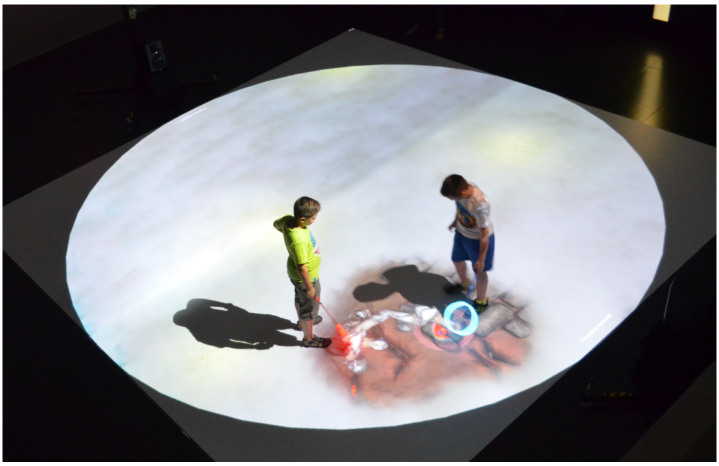


Figure 4.4: Users could continue playing for an undefined length of time, as there was no end point to the exploratory nature of the game.

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 (see Figure 4.4). Therefore we designed the game without 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, 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 this audiovisual feedback as game responses, the children could learn that when playing together, they would be able to experience a more exciting and surprising gameplay than when 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.

4.2.5 Procedures

A total of 68 children played in the system (34 children with ASD and 34 typically developing children) during seven weeks of trials in Barcelona and London. Evaluation criteria of the system focused on themes from the hypotheses such as motivation of the child to play in the system, propensity of the child to engage with other people, and visible social interaction attitudes. The experimental setup allowed information to be collected from three sources: video coding analysis, system logs, and parent questionnaires.

Each child with ASD played in the system for a duration of 15 minutes, which after a series of pilot trials, was deemed an appropriate length of time for the attention span of the children and also allowed time for each of the game elements to be explored. Upon arrival to each playing session, the child with ASD was introduced to a typically developing child who would serve as their playing partner for that day. Game playing instructions were standardized and basic, so children could discover on their own how to play the game, a practice which encouraged sharing of knowledge between the children while playing.

The system was tested in both a laboratory setting where children were recruited from nearby autism centers, and a school setting where children with ASD were integrated into classrooms with typically developing peers. In the laboratory setting, children attended three separate sessions with different partners, and in the classroom setting, players attended a single session. In both settings, it was assured that none of the children had a close existing relationship with their playing partner, so that each game provided a unique opportunity for the child with ASD to practice social initiation and response with a new companion.

4.2.6 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 typically developing 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, parents, and school professionals.

Evaluation criteria

The first evaluation criterion was that the system would motivate users to play. This was assessed through children's activity level and flexibility while playing the game. These factors were evaluated through responses to the post-session questionnaires and through system data such as distance (in centimeters) covered through the game, the amount of features of the game interacted with and time spent engaging in active game play.

The second evaluation criterion measured the increase in propensity of each child to engage with other people, i.e. an increase in social behaviors. This was assessed by observing the number of social bids, requests, and responses made by the child with ASD during the course of each session. In addition, we measured the number of social acts directly related to the game events and the perception of the game as a starting point for forming social relationships.

The third evaluation criterion was that the children would show collaborative actions while playing the game. As the game was aimed at fostering collaboration between the child with ASD and the typically developing child, we analyzed the number of collaborative activities and changes in the proximity between users to search for indicators of positive collaboration attitudes.

All collected data was first analyzed for its normality with a Shapiro-Wilk test. For normally distributed data, ANOVAs were used for independent variables with more than two conditions, while paired t-tests were used for intra-subject two condition data. For the non-normally distributed data we used a Wilcoxon test.

Given that the ASD screening criteria was different between the two locations, we tested for a difference in behaviors between the two studies' populations. No statistically significant differences were found.

Child Motivation

The motivation of children to play in the virtual environment was measured by the child's activity level and flexibility while playing in the system. This information was gathered through post-session questionnaires which were administered after each session to parents in the laboratory trials. In the case of the school trials, post-session questionnaires were filled out by a special education teacher after each child completed his or her session. A copy of this questionnaire can be found in the Appendix, Figure A.3.

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 the game 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 4.1), while the amount of hunted insects increased through sessions (ANOVA: $F(2,9)=16.9$, $p<.05$) (table 4.2). 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 4.3). This also supports the idea that children were demonstrating a consistent willingness to participate in gameplay through the course of the sessions.

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 4.4). 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

Table 4.1: 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 4.2: 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 4.3: Number of Seconds Still

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

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 4.4: 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, parents indicated through post-session questionnaires that the flexibility levels of their children increased through sessions (table 4.5), and the special needs assistant at the school reported in the post-session questionnaires 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 game's goals of exploring, sharing and adopting collaborative behaviors.

Table 4.5: Flexibility Level

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

Social behaviors

To measure the children's propensity to engage with others, video recordings of the sessions were reviewed and coded for social initiations, responses, requests, shared actions and spontaneous gestures (Appendix, Figure A.5). Results from interview questions related to the children's experience also helped determine the children's propensity to engage with their play partner during the experience.

Video coding of social actions In the controlled laboratory experiments, the amount of social initiations from the children with ASD increased through sessions (table 4.6), and the amount of responses by children with ASD also increased significantly from the first to the third session (ANOVA: $F(2,9)=8.049$, $p<.05$) (table 4.7). These results are illustrated in Figure 4.5. Responses were 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 4.8).

Table 4.6: 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 4.7: 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 4.8: 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 the 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 catalyst for sparking social opportunities during play.

Questionnaires The children also showed a tendency towards positive perceptions 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

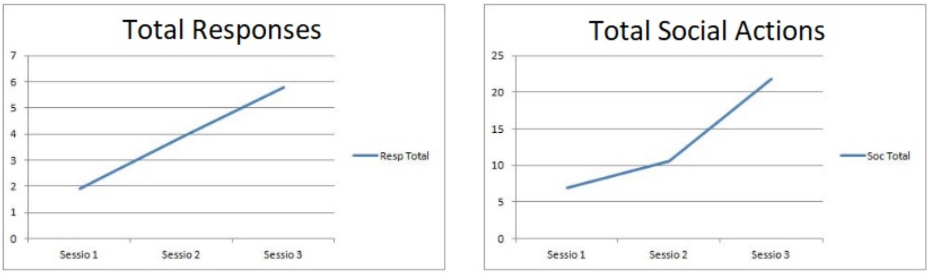


Figure 4.5: Video coding revealed a significant increase in responses and total social actions over the course of three experimental sessions.

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 developing children to see that children with ASD could be play partners. After playing in the virtual environment, 65 per cent of typically developing children in the inclusive school indicated that they would like to get to know their partner better after playing together in Lands of Fog.

Collaborative behaviors

To analyze the collaborative behaviors which occurred while playing in the system, we looked at the system mechanics which were completed when the two players worked together. Questionnaire items related to perception of playing with a partner also contributed to the analysis of collaborative behaviors.

System data 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 4.9). 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 4.10), in both the laboratory experiments and the 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 4.9: 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 4.10: 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

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 typically developing 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.

4.3 Design Study 2: Lands of Fog 2

From the paper *A Mixed Reality, Full-Body Interactive Experience to Encourage Social Skills in ASD Children: Comparison with a Control Non-digital Intervention*

Building on results from the initial study, the Lands of Fog system underwent a second prototyping process for a second round of experiments. The primary goal was to test whether practicing socialization in a virtual environment catered towards individuals with ASD could be a way to reduce anxiety while simultaneously forming collaborative behavioral patterns. This second phase compares our system to a typical LEGO social intervention strategy using construction tools and toys as an aid to the psychologist, therapist or caregiver. Results are based on four data sources: (a) video coding of the externally observed behaviors during the video recorded play sessions (b) log files of our system showing the events triggered and the real-time decisions taken; (c) physiological data (electrodermal activity and heart rate variability) gathered through child-appropriate wearable; (d) and a standardized anxiety questionnaire. The results obtained show that the mixed reality setting generated as many social initiations as the control condition, and no significant difference existed in the reported anxiety levels of the children after playing in the two conditions.

4.3.1 Motivation

This study built upon the results from a previous study which indicated the potential of a mixed reality intervention in fostering social and collaborative behaviors in children with ASD while engaged in exploratory play with a non-ASD partner. In the present study, we developed an experimental protocol using standardized and objective data collection (see Figure 4.6). A control setting was arranged using elements of LEGO play therapy, a common tool in social skills training for autism. The primary goal was to test whether practicing socialization in a virtual environment catered towards individuals with ASD could be a way to reduce anxiety while simultaneously forming collaborative behavioral patterns. A secondary goal was to test multimodal data collecting methods to detect changes in the children's willingness to collaborate and their active state throughout. To detect willingness to collaborate, we used system data logs and video coding of social and collaborative behaviors. To detect changes in their active state, we used physiological response indicators of electrodermal activity (EDA) and heart rate variability (HRV), and used a standardized questionnaire to detect anxiety state. As the results of the physiological study will be described in detail in another paper, this report will focus on results from the other three data collection methods in comparison to the LEGO play therapy condition.

Figure 4.6: The Lands of Fog 2 focused on standardized and objective data collection to explore links between game events and changes in the children's internal state.

To test the link between social behaviors elicited in a virtual environment and changes in internal state, we used the Lands of Fog system. For the current project, we developed a formalized experimental protocol to test the system in comparison to a standard activity used in naturalistic therapy for autism, which used LEGO play blocks. In addition, we expanded the data collection to include video recording, system logs, standardized questionnaires, and physiological data (electrodermal activity and heart rate variability) while the children were playing in both settings. Our research into collaborative play patterns revealed that shared goals can serve as a tool for collaboration, so we also developed a goal-oriented alternative for the initially open-ended play environment.

4.3.2 Background

The first intervention strategies for autism had roots in behavioral analysis and positive reinforcement of desired behaviors, as early as the 1970's. One such method was Applied Behavioral Analysis (ABA), which focuses on on how changes in the environment might affect behavior. Based upon this emphasis of environmental factors, the search for intervention practices in a natural environment has led to the emergence of Naturalistic Developmental Behavioral Interventions. These interventions are unique in their balance between the child's and therapist's control. This practice is based upon the developmental psychology idea that children's learning is bolstered by their position as active participants in the environment. These intervention strategies may have a general focus, or may focus on a specific area like social skills, such as Social Communication/Emotional Regulation/ Transactional Support (SCERTS) [Prizant et al., 2006] and the Early Start Denver Model [Rogers et al., 2012]. However, the heavy burden on caretakers due to intensive treatment times has led to the search for digital intervention tools which seek to relieve the amount of manpower necessary to carry out treatment.

4.3.3 Design Strategies

Drawing from the results of the first trials, we were able to identify weak points in the design of the system, and made several notable adaptations. The hardware configuration remained mostly unchanged. However, new handheld pointers in the form of butterfly nets were designed which offered increased robustness, as we had observed that the original nets wore down quickly due to rough movements during physical activity of the children in the environment. New nets were designed which integrated batteries inside of the handle for balanced weight, allowing for the wires to remain concealed away from the children's reach. A color changeable LED wire was introduced which could be configured to a range of colors. While the original net design made use of electro luminescent wire, which had to be looped around the net multiple times to create a thickness detectable by the tracking cameras, the introduction of LEDs offered increased visibility to the color detection cameras which tracked the children's movements.

We saw that the children were able to explore the majority of the interactive elements during a 15 minute play session, so a second map was added with additional interactive elements. As the first map had been designed by a group of male children with autism through participatory design workshops, a female was involved in the design of a second map, which was a beach scene. A bottle prop was added which revealed the hidden map and could be used as a portal between worlds when the children worked together. The simple interaction of coming together by the bottle was meant to serve as a first introduction to how working together could activate interesting results from the interactive elements, called props. We also added interesting outcomes of manipulating the props, such as the possibility to collect two halves of a gold key.

In order to test the effects of goal driven play, we created an alternate version of the game and added a door in the center of the environment. Through the manipulation of props scattered throughout the environment, children were able to find keys to unlock the door. To test this, half of the children were told that their goal in playing was to open the door. The other half were simply told to explore the world together with their partner and discover things to do. Both versions of the game contained the same form of interaction design and interaction possibilities.

Additional small changes were added to address shortcomings in the game design. For example, a bug existed when a creature was changing its texture and began to merge which was fixed. The speed of copying a creature when a merge occurred was improved, and specific prop manipulations were improved. Other changes included changing the darkness of shadows below creatures, lightening specific textures that showed up too dark with the light rendering (the shark and the dragon), making the fog more opaque, and a longer time frame was added between prop manipulations. A log message was added to aid in coordination between physiological sensing start time which linked to an audio cue to indicate the video coding start time.

4.3.4 Procedures

In this experiment, we decided to test the system with pairs of children, with one child with autism and one child without autism. This allowed us to replicate the setting that could be found in a mixed cognitive abilities classroom, and also to spread awareness to the non-autistic community of the potential of children with autism as playing partners achieving better social integration of the children with ASD.

Experimental Procedure

The experimental sessions were divided into two parts: the Lands of Fog condition, and the LEGO based control condition, each lasting 15 minutes (see Figure 4.7). For the LEGO condition, the activity was modeled after an activity found in social skills therapy, where a group of children is asked to work together to complete a short task using LEGO blocks. In our case, the children were asked to find a set of lost LEGO figurines, then build a ship for the figures. Each pair of children played once in both settings, and the order of conditions was randomly assigned to counterbalance the effect of order of tasks.

At the beginning of the session, each child was introduced to the experimental setting, which was a laboratory at the university. Parents of the children, two researchers, and a psychologist who ran the sessions were present. Taking into account the emotional sensitivities that could occur with children with autism during the experiment, the psychologist began the session in a manner similar to a therapy session, by introducing concepts related to anxiety. This was done with a visual support called Jumby is Calm which is used in social skills therapy, relying upon visual cues as a tool to anticipate outcomes of the new situation [Gallo and Annenberg, 2009]. This was intended to introduce the concept that adaptive anxiety was an expected feeling during the experiment. Children were then introduced to the materials used during the experiment, shown a brief video of how to hold the pointer devices, and were fitted with sensors for the physiological sensing. These sensors were integrated in a wearable we designed to make it fun and acceptable by the children. Thanks to this, most children did not show discomfort at wearing the sensors, but some were wary about removing the adhesive pads. Before and after each condition, children responded to interview questions administered via tablets.

Additionally, separate goal oriented and open-ended version of each condition were developed. For the Lands of Fog condition, goal-oriented sessions began with the psychologist instructing the children to play the game for 15 minutes, and the goal was to find parts of a missing key to open a door which appeared in the center of the environment. When the children entered the scenario, a single object appeared, and once the children learned to manipulate the object together, many other objects appeared which could be interacted with. In the open-ended condition, children were initially told that they could explore the scenario together with their partner and many object possibilities were present from the start of gameplay.

In the LEGO condition, goal oriented sessions began with the psychologist showing a picture example of a LEGO boat, and instructing the children to build that boat together. In the open-ended sessions, children were told to build a boat together, with no example or guidance of how to carry out the task.

Figure 4.7: As part of the comparison study, children played for 15 minutes in the Lands of Fog condition and 15 minutes in the LEGO condition with a partner.

Population

Children with autism were recruited through the Hospital Sant Joan de Déu in Barcelona, which has a specialized unit dedicated to autism. This hospital is renowned for its clinical practice, as well as its research on child's health. Non-ASD children were recruited via flyers distribution in educational centers near the university and via social media diffusion. A total of 36 children between the ages of 8-12 years old participated in the study (N=6 female, N=30 male). The study recruited high-functioning children with autism who had a diagnosis for autism determined by the scale of Observation for the Diagnosis of Autism (ADOS) module 3, designed for young people with verbal fluency, with a minimum severity diagnose of 4 [Lord et al., 2001]. Non-ASD children were those with no diagnosis of autism or any other condition. Both ASD and non-ASD had to score a minimum IQ of 70 as determined by the Wechsler Intelligence Scale for Children [Wechsler, 2014].

Data gathering and analysis

All sessions were video recorded via two GoPro cameras that provide a wide angle view of the whole interaction space, stationed at opposite sides of the play arena. We used external high quality microphones connected to the GoPros to acquire good quality sound in the video recordings since the conversations are crucial to understand and code the social behaviors. Videos were cut into 5 minute sections, and the first and last 5 minutes of both the experimental and control conditions were coded for social behaviors including social initiations and responses.

To gather data on the child's trait anxiety level and the changes in anxiety level before and after each experimental condition, we used a standardized questionnaire called STAIC (State-Trait Anxiety Inventory for Children) [Spielberger, 2010]. Questions were read aloud to the children from a tablet by the psychologist of the team, although children could also read the questions and mark their responses. Parents also filled out the CBCL (Child Behavior Checklist) [Achenbach et al., 2012] prior to experiments, and the project's psychologist also held interviews with the children after each condition to understand the children's reception to the games and collaborative activities.

Physiological data was recorded using a Biosignal PLUX device hidden in a wearable in the shape of a super hero's cape. This device recorded heart rate viability (HRV) and electrodermal activity (EDA). Sensors were placed on the children's neck and chest at the beginning of the trials, and remained in place through both experimental conditions. A wireless transmitter on the device allowed the children to move freely while data was sent to a computer in the same room.

The Lands of Fog system also recorded data on player activity through internal logs. This data recorded a timestamp when players triggered individual and collaborative actions. The system also tracked and recorded player movement through the scenario, such as user position from which we could obtain distance between users, heat maps of main exploration areas, velocity of movement, and smoothness or jerkiness of motion. After the trials, the logs were parsed to distill an overall view of player progress through each session, and to triangulate moments of collaboration in the system.

4.3.5 Results

After data collection, results were extracted to determine the system's efficacy in supporting social interactions between the children. Of particular interest were differences between the LEGO and Lands of Fog conditions, and differences between sessions where the children engaged in goal oriented or open-ended play. This sections contains information from analysis of video coding recorded social behaviors, questionnaires, and game log files. The analysis of the physiological data will be undertaken as part of the thesis of Batuhan Sayis.

Video coding of social behaviors

As all children participated in both conditions, a paired-samples t-test was used to search for significance ($p < .05$). No significant difference was found between the number of initiations made by children with autism between sessions playing Lands of Fog and the LEGO control condition. During the first 5 minutes of play, children made significantly more responses $t(16)=-2.37$, $p=.031$ in the LEGO control condition ($M=4.29$, $SE=.751$) than in the Lands of Fog condition ($M=2.56$, $SE=5.82$). We also saw a significant increase $t(16)=-2.048$, $p=.05$) in the number of responses during the last 5 minutes playing Lands of Fog ($M=5.25$, $SE=1.27$) than the first 5 minutes ($M=2.56$, $SE=5.82$). We also saw a trend $t(16)=1.912$, $p=.074$ of more non-verbal behaviors in Lands of Fog ($M=4.88$, $SE=1.131$) than in the LEGO control condition ($M=2.76$, $SE=7.93$) (see Figure 4.8).

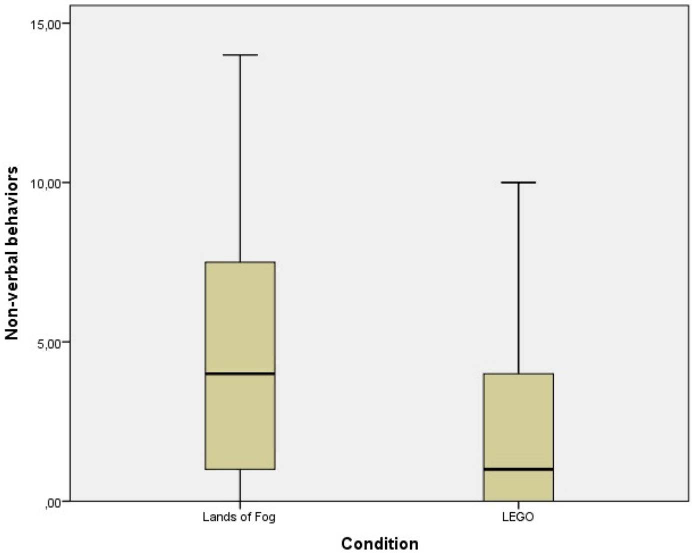


Figure 4.8: A significant difference was observed in the occurrence of non-verbal behaviors between the Lands of Fog and LEGO conditions.

Questionnaires

A Wilcoxon's signed rank test revealed that the children with autism felt like they knew their partner significantly more after both the LEGO control condition and the Lands of Fog condition than before the experiments. No significant difference was seen in the reported anxiety levels after either condition. When the children were asked what the purpose of the activity had been, non-ASD had a higher tendency to report comments such as "meet others" and "trust in others", and children with autism focused more on aspects related to the game concepts such as "unlocking new worlds" and "catching the insects."

Game log files

The game log files were filtered for actions occurring within 10 seconds before or after the child with autism made a social initiation. The most common game events occurring within 10 seconds of an initiation were hunting insects and greetings made by characters when they came in close proximity with the other player (see Figure 4.9). However, hunting insects and greeting other characters had the highest prevalence of total occurrences during the sessions, so although they accompanied social initiations most frequently, the percentage of times that those events led to a socialization was relatively low. The least common events to accompany a social initiation were creatures merging, manipulation of props, and creatures changing textures. Because these events happened much less often during a session, the percentage of times that these events led to a social initiation was much higher.

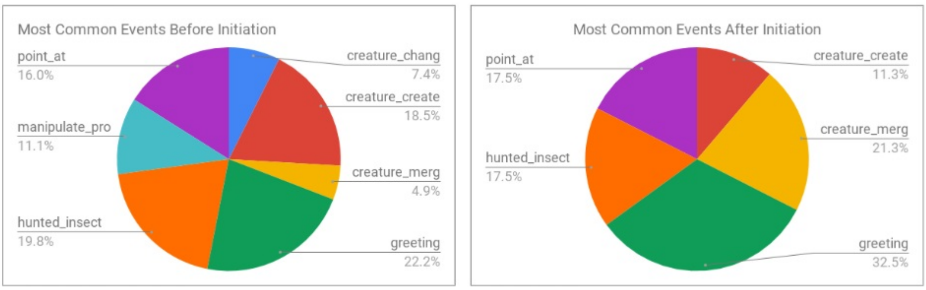


Figure 4.9: Most common game events occurring immediately before and after social initiations

When we separate the events which occurred before an initiation from the events which happened after an initiation, we see that although prop manipulations occurred before initiations 11.1 per cent of the time, these prop manipulations never happened after an initiation. In contrast, creature greetings were more common after an initiation (32.5 per cent) than before (22.2 per cent).

Open-ended and goal oriented play

When we searched for a difference between goal-oriented and open-ended play sessions, we did not find any significant differences between the social behaviors in either condition. However, we saw that the goal-oriented condition elicited a higher mean number of social behaviors for initiations, responses, externalizations, and high level behaviors in the Lands of Fog game. When we compared system events which occurred in the goal-oriented and open-ended conditions of Lands of Fog, no significant differences were found, although there was a higher mean number of insects hunted in the goal-oriented condition. There was a slightly higher mean number of creature mergings in the open-ended condition.

4.4 Design Study 3: GenPlay

This section is based on the article *GenPlay: Generative Playscape* [Crowell et al., 2018]

The goal of the GenPlay study was to orient the use of technology in a participatory and collaborative way that integrated children with ASD into the classroom, ultimately fostering socialization in a classroom environment in order to facilitate social integration.

4.4.1 Motivation

As classroom observation has revealed a lack of adequate educational support for school professionals, the principal motivation was to supply novel resources to the teachers of integrated classroom settings which would serve as a support for increasing inclusion during playtime activities. On a larger scale, this research project focused on the specific properties and evaluation of full-body interaction design of multi-user mixed reality environments created specifically for the classroom integration of children with Autism Spectrum Disorders through playful experiences (see Figure 4.10). Therefore, we also aimed to improve their understanding and adoption of social behaviors with peers and with society in general.

The main setting of the research was a large scale floor-projected virtual environment, which allowed testing of interaction strategies and evaluation methods of experiences based on collocation of multiple users within a full-body interactive scenario, where they could use motor and gestural movements to practice interaction in a natural and uninhibited manner.

Figure 4.10: GenPlay focused on player collaboration in a classroom space.

The primary motivation for creating a new system came with the selection of media components. Although Lands of Fog had been useful in fostering integration in a school setting, the large footprint of the system (6 x 6 x 4 meters) required extended use of a large space, which became a barrier for conducting longitudinal trials. Therefore, we chose to create a new system with a decreased footprint of 2 x 3 x 1 meters, consistent with the size of a standard classroom space, and use a frontally aligned motion capture camera (Kinect) instead of ceiling cameras to decrease height requirements. With the Kinect came a new dimension of camera vision capabilities, thus we explored development possibilities to detect for a finer resolution of interactions by involving gesture recognition of hands and feet. To collect parameters for development of the system, we carried out a design study which first included contextual analysis and later usability bench marking with child users.

4.4.2 Background

As tools to diagnose ASD become more defined and autism gains more recognition in the field of research for intervention disability technologies, many potential aids have been developed to ease the burden on children, parents, teachers, and other stakeholders. The use of digital interventions are increasingly important due to flexible content customization, natural interaction, and easy integration into classroom and hospital spaces.

Although interventions for children with ASD have dealt with various aspects of the condition, such as motor control irregularities and difficulties in sensory processing [Tentori and Hayes, 2010], the research project primarily dealt with the development of social behaviors. Three previous research studies involving full-body interaction increased our understanding of the relationship between ICT exploration and social behaviors in children with ASD.

The project *Lightpools*, also called Ball del Fanalet [Hoberman et al., 1999], was an interactive art display which explored open-ended interactivity between users and a virtual space. The display consisted of a circular arena where virtual objects were projected below users, which users could train to acquire various dance patterns, allowing for a constantly evolving interaction dynamic. During a special school visit to the arena, researchers and school professionals observed an increased level of social interaction between children with ASD, stemming from a desire to share their discoveries with nearby spectators. Using the previous project as inspiration, *Pico's Adventure* was developed as a motion-based playful experience for children with intellectual and motor disabilities [Malinverni et al., 2014], focusing on children with ASD as the target user group. The project used a Kinect tracking system and a large LCD display to project the child's image into a virtual environment. As had been seen in other studies [Alcorn et al., 2013], unlikely combinations aimed to elicit social behavior from surprising discoveries, i.e. a piece of cake growing on an apple tree. Participatory design studies with children helped develop game content, and psychologists aided in defining the project goals based on social therapy practices: social initiation, approaching others, and producing verbal or gestural behaviors.

Next, we created a virtual environment developed specifically for fostering social initiation behaviors in children with ASD. The project was based on an open-ended form of interaction in a large floor projected exploratory space with overhead player tracking cameras, similar to Lightpools. The system, called *Lands of Fog* was designed for children with ASD to play with peers in a large circular arena, obscured by a dense virtual fog where they could discover the virtual world through collaborative play.

As seen in the aforementioned studies, full-body interactive systems present an opportunity for children to practice social behaviors and have a positive collaborative experience with peers. The GenPlay study was founded on the hypothesis that this technology could serve as a way to aid teachers in their work managing the disparity between each child's needs.

4.4.3 Design Strategies

To select the technological medium, we based our selection on our goal of building a classroom-adaptive system that would allow the children to explore generative audiovisual stimuli. To engage the children with these audiovisual stimuli, we needed a much finer resolution of gestures in the full-body interactive system than in the previous Lands of Fog project. Instead of just mapping the children's movement on a two dimensional plane, we aimed to include jumping, stomping, swiping, and scooting. As our system called for a larger breadth of actions than the previous system, we decided to use a Kinect camera, which allowed for skeletal tracking. Suddenly, the height of the hands and the speed at which the feet moved gained meaning in the scope of the interaction.

The first phase of designing the new system included field visits to a local school for children with language disabilities. Roughly 40 per cent of students had been diagnosed with ASD. The field visits included two phases. First, a researcher sat in on class activities, observing the classroom and playtime interactions between teachers and students. During the second phase, researchers visited the class for three workshop sessions, where activities were planned to understand the propensity for grasping symbolic play with peers. Additionally, interaction research included providing the children with joint activities where students had to use both fine and gross motor skills, such as popping soap bubbles or modeling clay figures. Analysis of the sessions revealed a preference towards highly structured content, personalization, and building upon work done by others. Workshop activities are described in detail below.

Codesign activities

The design of Genplay included codesign activities with a special needs school in Barcelona, which taught children with conditions related to language development. Researchers first held interviews with the director and speech therapists of the school to understand which obstacles hinder integration of children with autism in mainstream schools in Catalonia. The speech therapist told that using technology in the classroom had helped to teach children sharing and cooperation. Teachers also collaborated with the researchers to arrange several workshop design sessions during school hours (see Figure 4.11). The class who participated in the workshops consisted of eight children 10-12 years old, of whom three had autism.

The first workshop consisted of informal observation of routine classroom activities, such as describing and spelling out words in Catalan. This helped the researchers benchmark the level of understanding and language fluidity of the children, as well as observe the challenges facing educators who needed to communicate effectively with these children.

At the special needs school, children engaged in recreational activities of a free play nature on an outdoor patio during break time. This outdoor patio served as the setting for one design workshop. Two play arenas were drawn in chalk on the children's patio space, and children took turns standing opposite a partner in one of the arenas. The size of the arenas was approximately equal to the proposed game projection area. One arena was circular, and the other was triangle shaped. Children were given small bouncy balls and instructed to play within the arena with the balls. When they collaborated with their partner (including passing the ball, creating rules together), children were given an additional ball. Researchers observed that the circu-

Figure 4.11: Children were involved in the design of the system through taking part in classroom workshop sessions, focus groups and usability trials.

lar form fostered more flexibility in player arrangements, as triangle-bound players tended to restrict movement to a corner. The teachers were eager to assist the children in the activity, and it seemed as though their support was a vital part of drawing out the children's creative abilities. This led to the decision to include teacher participation in the game design.

In another workshop, children were instructed to draw their favorite toy. Then, researchers presented the children with a large box full of many tiny round pebbles. Children had to create a story with their toy drawing in the box. The purpose of this activity was to understand natural interactions and interpretations with particle-like objects, identify children's interests, and capture natural gestures of exploration. Many of the drawings depicted gaming consoles like iPads or Playstations, which made narrative construction difficult. Later, children chose a game character from those consoles. Only one child drew a physical being, which was her puppy. When children were asked to explore the pebble box and say what it reminded them of, this activity was challenging for the children, especially the first ones to go. Researchers originally left the instructions open to the children's interpretation, but eventually went back and added structure and clarification to the activity. Children found it easier to build their story upon the previous child's, to create a world' where all the characters lived together. Of particular interest to the children was how their character could contribute it's strengths to the world to help others. This helped to understand the level of abstraction which children were able to support, and that they would need a context and something to build upon in the game.

Contextual analysis

Following the initial field visits, the student research group convened for requirements planning and sketching basic iterations of the project. To our understanding, the system would need to encourage collaborative exploration through generative audiovisual stimuli, full-body interaction between multiple users, must be fit for classroom and therapy settings, and have a clear interaction mapping.

Next, we outlined our stakeholders and their individual needs in a mindmapping format, and approximated each user's interaction experience with the system. We highlighted the most essential stakeholders, which would be the teachers, school directors, psychologists, parents, and the children themselves, and set up stakeholder interviews with each group to understand their current situation and needs.

Following expert interviews, we discovered several points that could be addressed in the design prototype for our full-body interaction experience. The most difficult point for a school is the social reintegration of ASD children to an ordinary school. Therefore, our set-up aimed to give autonomy to each child and give importance to the contact with their peer. Following information from the teachers, we decided to use the advantages of technology to create social interaction by making them share an activity with one interactive space, encouraging multiple individuals to play a collective activity through one device. This fosters social regulation and improves communication abilities. Also, feedback from the caretakers of children with special needs was given, such as incorporating personalized parameters to raise children's motivation with the choice of their favorite color as a reward.

Usability benchmarking

Next, we developed an initial prototype of the system which would allow us to test basic interactions and movement of users within the space (see Figure 4.12). We first conducted usability testing with 40 children from an inner city school in Barcelona. Users were divided into pairs, and asked to verbalize their observations and assumptions while playing in five short versions of the system. Afterwards, we used the participatory design technique of giving the users modeling clay and diagrams depicting the projection space, asking them to model their play experience and how they would improve it to be used in their own classroom. We observed that, while the setting fosters exploratory interactions, children from 8 to 12 years-old seem to be focused towards task-oriented activities, as well as require reward to foster motivation. We also sought a proper balance between the visuals, interactions and the eye-contact between children so that they maintain social contact and not start playing alone.

Figure 4.12: A prototype of the system was developed for usability testing (left) and later improved for classroom trials (right).

We iterated the software and game flow according to initial findings, and tested the game again with a different group of 20 children, ages 11-16. With these users, we tested eight different versions of the game, each with a short iteration of an exploratory particle system and one with a more concrete goal. After the trials, we conducted user interviews asking how they would change the game. Interestingly, all of the participants agreed that their favorite had been the scenario with a concrete goal, but we observed a higher level of social interaction (through verbal bids) during the exploratory format. Following this, we discussed how to mix the particle systems into the structured scenario, so that children could focus on fine interactions and also have a sense of orientation in the game.

Finally, we ran two trials involving mixed pairs of children with ASD and typically developing partners. Observations in the game indicated that when a task is not properly set, the child with ASD tended to imitate the behavior of the other child in order to understand the game. We also observed social interaction consistently when players were focused on the exploration of the generative graphics.

Once the decision was reached to use generative graphics, we developed two versions of the game. One version made use of representative graphics, such as those in the Lands of Fog system, and the other version made use of abstract graphics (see Figure 4.13). Representative graphics were considered those with the form of real objects, using photo-realistic assets. In our case, we used the images of a shark and the texture of water. Abstract graphics were considered those which did not directly represent recognizable objects, and were completely composed of polygon meshes, particle systems and metaballs. The interaction breadth and possibilities in each of the environments were balanced; the difference was only in the graphical content.

For this study, undertaken as part of the master thesis of Joseph Cumeras Khan, we hypothesized that children with ASD would show more social initiation with a peer when interacting in an environment with abstract generative visuals compared to when interacting with representative generative visuals.

This hypothesis was partly based on observations made in a previous project from of Lands of Fog, where we observed how the children interpreted the visuals in unexpected ways and started conversations around what they were seeing. The idea behind using abstract visuals was to further fuel the imagination of the children to see if they would start conversations about their own interpretations. This was particularly interesting, as children with autism show difficulties with symbolic play, but at the same time, demonstrate increased abilities with computerized systems.

Furthermore, we believed that abstract, math-based visuals may take less resources to develop compared to modeling 3D or 2D assets. If these more efficient visuals proved to be as good as more intensive visual solutions in fostering social initiation they would become valuable resources for future projects.

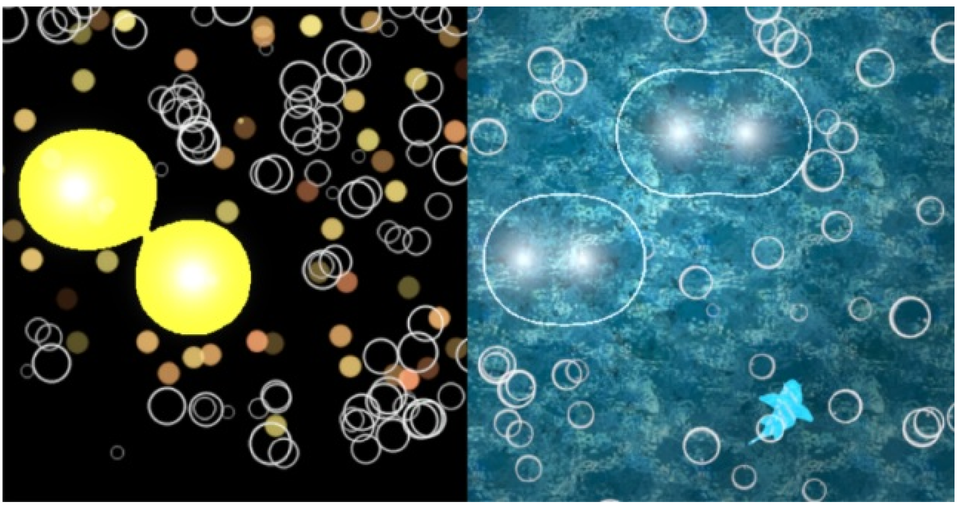


Figure 4.13: An abstract version of the GenPlay game was compared to a representative version.

4.4.4 Procedures

In spite of the fact that the system was created to be used in a mainstream classroom environment, for the purpose of this study we conducted trials with the Escola Fàsia, a school for children with language impairments, working a classroom which had participated in the design workshops of the system. A total of 14 children participated in the trial sessions, and in each pair, one child had ASD and the other child had another type of language impairment which was not autism. Each pair played once in the abstract environment for 5 minutes, and once in the representative environment for 5 minutes. The order of representative and abstract settings was randomized. Data was collected via system logs, video coding, and questionnaires from the teachers.

4.4.5 Results

Although the representative condition showed slightly more social initiations by the children with ASD, no significant difference was found between the two conditions when sessions were video coded (see Figure 4.14). In contrast, the children with ASD showed a slightly higher number of social responses in the representative condition. No significant difference in the mean distance between players was found between abstract and representative conditions. When teachers were asked via questionnaires to determine whether the children's social behavior was more or less than normal, teachers responded that all children's behavior was more social than normal in both conditions. No significant differences were found between sessions in the perceived level of social behaviors.

The lack of significant differences between conditions showed that the choice of abstract or representative graphics in the classroom-based system had no significant effect on socialization, placing abstract visuals as a viable alternative to representative visuals in digital systems for autism.

A final version of the game was developed as a result of the above design study. The visuals consisted of spatial interactions with abstract generative

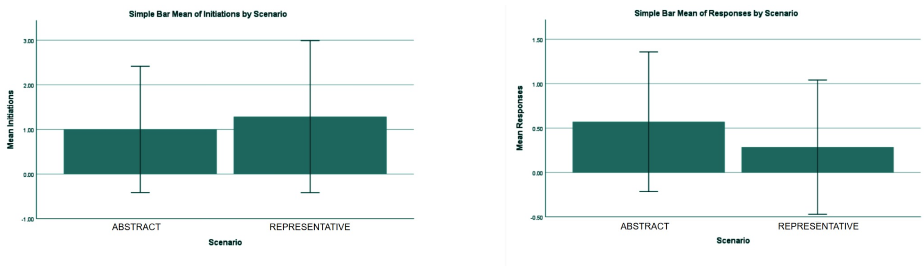


Figure 4.14: Initiations and responses by children with ASD

graphics based on particle systems, which could be interacted with or flow gently through the scene when left alone. The number of particles increased as the children got close to one another. As soon as the users were detected by the Kinect camera, they got two luminescent placeholders each, one per foot. The placeholders followed the movements of their feet in the virtual environment, dictating the communication between it and the real world. When children got close in proximity, the placeholders gradually grew into a warm red color.

Initially, particles emerged from the user and shifted around the space, creating interesting effects when the two players come together. Users could collaborate to collect virtual objects with unique capabilities, such as changing colors, firework-like explosions, or acting as a net to capture nearby particles, behaviors aimed to capture the attention of children with ASD, with higher sensitivities to their environment.

Classroom trials were held in Netherlands with 57 children of mixed cognitive abilities. A description of this study and corresponding results may be found in Chapter 5.

The design study was influential in developing the final version of the system, and we continued to explore variations of the generative audiovisual aspects of the project through alternating development work and usability trials. The experience was educational in the sense of working through difficult issues related to designing for our user group, the most vital of which included leveraging abstract elements with the children's need for consistency and structure, and leaving space for both individual and collaborative play.

Future work should explore the implementation of a more robust tracking system, as the Kinect was designed to function best with front-facing alignments, while the GenPlay system was based on the premise of an exploratory space where children could move freely in all directions. Also, free movement was limited by the reduced projection space inside of the classroom environment, which might have reduced individual space and exploratory behaviors. The project called for a stronger empirical evaluation through systematic videocoding of social initiation behaviors, including longitudinal *in situ* trials in an integrated classroom space, to explore the system's potential as a positive influence on collaboration.

4.5 Summary

Following data collection and analysis from carrying out experimental studies with these three systems, I began to explore which interaction design elements had impacted the children's play experiences with a partner. For the purpose of this thesis, discovering that children had been willing to socialize with a partner in the systems was only the first step. The more important question was related to finding which specific elements of the system were most successful in building these social moments. The following chapter will aim to explain the interaction design components of the systems and understand the impact they had on the children's play experiences.

Chapter 5

Contributions in Full-Body Interaction Design for Fostering Socialization for ASD

5.1 Introduction to this chapter

In this chapter, we will review insights from the various interaction design approaches used in the projects of this thesis. Each concept will be described using one or more case studies where it was implemented. First we will introduce each concept and provide relevant background information, then introduce the case study and methods used for testing. Next, we will discuss key results and observations, then provide insight into implications for using these interaction design methods.

This section will begin with an introduction to the concept of Encouraged Collaboration, which has been used to give users positive feedback for collaborating, while providing ample space for independent play. We see that this method is especially adequate for children with autism, as it allows them space to ready themselves for social interaction, while fostering positive and social collaboration behaviors. Next, we will discuss how open-ended play might be configured for users with autism. Then, we will discuss how proxemic distances can be understood for users with autism, in the case of systems with unique spacial configurations of users. Finally, we will describe how the contextual elements of the interactive space can affect understanding of users.

5.2 Encouraged and Enforced Collaboration

Collaboration occurs when two or more people coordinate related actions to achieve a common goal. Social activities such as collaboration lead to the development of cognitive skills based on active participation in the environment and learning from the tools and conversations within the social context [Rogoff, 1990]. Collaboration calls for a shared understanding on a common focus of attention, which forms the grounds for communication. According to Vygotsky, the human mind is inherently social, and the development of cognitive processes is mediated by discourse and intersubjectivity [Wertsch, 1985], using tools such as verbal and non-verbal language [Forman, 1992].

Collaborative scenarios can be beneficial to practice social skills for individuals with social difficulties, such as children with ASD. Mundy et al. [Mundy et al., 1986] observed that individuals with ASD showed significant deficits in the use of joint-attention abilities, or "coordinated attention between interactive social partners with respect to objects or events in order to share an awareness." As collaboration is agreed upon through social communication, collocated mediated collaborative scenarios present an ideal approach for individuals with ASD to scaffold the learning of social behaviors such as requesting help, turn-taking, and sharing knowledge through social initiation and joint-attention.

Through collaborative settings, social behaviors are put into practice in a scenario where participants of the task have a shared goal, such as a problem solving situation. Thus, collaboration is built upon three processes: communication between group members, coordination of shared goals and responsibilities, and problem solving of given tasks [Dillenbourg, 2002].

Designing scenarios which offer children with ASD the opportunity to scaffold collaboration with a partner might be a useful way to aid in social interventions, by creating opportunities which allow for peer-to-peer communication similar to real life situations. Designers must keep in mind the level of freedom offered to players experiencing these collaborative moments, and structure the system's parameters accordingly.

In the following sections, we will offer an overview of various methods and classifications to structure collaboration in technologies for autism and their observed outcomes in our projects, which have been grounded in the principles of embodied interaction. First, we will present the background to the use and properties of digital technologies for scaffolding collaboration in children with ASD. We will then include a review of existing digital solutions for scaffolding collaboration, categorizing projects based on their approach to collaboration. This categorization will be based on an already existing classification proposed by Benford et al. [Benford et al., 2000]. Next, we will describe collaboration methods employed in the design of two full-body interactive systems which we have developed and evaluated to foster social behaviors in children with ASD. Finally, we will describe the experimental results of both projects and discuss the implications of using various methodologies of collaboration, from which design for future collaborative projects could be informed.

5.2.1 Background

Structuring digital technologies for collaboration

The use of collaborative scenarios has been widely applied in research on digital technologies for fostering socialization between peers [Khaled et al., 2009]. Much research has focused on using collaborative interactive experiences for fostering social behaviors in users with social impairments [Hendrix et al., 2009], such as ASD [Battocchi et al., 2009, Holt and Yuill, 2014, Hourcade et al., 2012, Millen et al., 2011, Mireya Silva et al., 2015, Piper et al., 2006, Tang et al., 2015, Winoto and Guan, 2016]. The use of technological devices specifically as mediators for collaborative learning could be motivated by their ubiquity and engaging nature, which can be a reward in itself for children with ASD [Hourcade et al., 2012].

Collaborative scenarios allow for unique user configurations, including the physical distribution of the users when participating in the collaboration activity. Systems can be designed to allow for collocated configurations, where users are present in the same physical space, or non-collocated configurations, where users work on the same digital task but from different physical settings (e.g. accessing the same virtual environment from different desktop computers through an Internet connection). In addition to the users' physical distribution, technological settings allow for designing experiences with specific user work patterns. These patterns include working on a task individually (on their own), cooperatively (in parallel with other users), collectively (with the same contribution made by all users) or collaboratively (actively working together towards a common goal).

Gradients of structure

In addition to user configurations, the use of technology also offers a high degree of customization with regard to structuring collaborative experiences. Projects can range from free play scenarios to highly sophisticated scripts for enforcing collaboration, with the intent of optimizing productivity, creativity or desired skills.

One objective of structuring collaboration is to create an even balance of user involvement, with the intention of optimizing efficiency and probability of successful outcomes. This can be both achieved through **game mechanics** which positively reinforce desired actions, or through **human mediation** by a teacher, tutor, or psychologist [Boyle and Inmaculada Arnedillo-Sanchez, 2015]. Balance may also be achieved by allowing for **joint actions**, where both users must complete the same action simultaneously, which may be implemented into the game mechanics to bring children together.

In the case of interactive storytelling applications, some projects may lead the user through **narrative formation** and offer users the choice between various plot options [Giusti et al., 2011] [Cassell and Ryokai, 2001], such as creating dialogue with characters or solving a problem, or towards a **shared goal** for players to complete together.

Another common method of structuring collaborative systems is to assign **user roles**. These roles may be symmetric or asymmetric, according to whether users perform the same or different, complementary tasks [Shah et al., 2010]. These user roles can be assigned randomly, or based on criteria such as domains of expertise [Dillenbourg, 2002] or needs [Hendrix et al., 2009]. By creating positive interdependence among group members through assignation of user roles, the users must cooperate in order to reap the full benefits of each user's abilities and knowledge [Hernandez-Leo et al., 2012]. Similarly, limiting the resources available to users may encourage users to practice social skills in negotiating the use of existing materials.

In less structured systems, users may decide their own rules of play, forming narratives and plotlines spontaneously while playing. In a controlled experiment with typically developing children, Bekker, et al. compared **free play** versus pre-set game scenarios [Bekker et al., 2008]. Children had more fun in the free play scenario and had the opportunity to practice various social skills, such as inviting others to play, while deciding their own gameplay procedures. However, free play also carries with it the potential for disruptiveness. When typically developing preschoolers were given Kidpad, a free play device for collaborative drawing, researchers observed instances of children sabotaging the drawings of their peers [Sylla, 2013]. In addition, the lack of assigned user roles often leads to the emergence of a natural leader, which can result in the over-dominance of one player [Bachour et al., 2008, Bekker et al., 2008].

In full-body interactive systems, users working alongside one another may benefit from **clear visibility** of the other's actions, motivating engagement and collaboration in each other's activities. Along this line, Yuill and Rogers identified three mechanisms that underlie the interactions of successful multi-user collaborative interfaces: mutual awareness of other users' actions, the degree of user control over the actions within the system, and availability of background information [Yuill and Rogers, 2012]. The sources for these mechanisms can be the physical interface, the software design and the users' cultural background. According to Yuill and Rogers, by carefully arranging these properties of the system, collocated experiences can be successful in promoting collaborative behaviors. Drawbacks for structured collaboration include less individual autonomy, restricted opportunities for user expression and creativity, and frustration from being made to perform a forced activity.

For Benford et al. collaboration strategies can be classified along a "collaboration continuum" depending on the level of freedom or constraint given to user activity [Benford et al., 2000]. At one end lies "enforced collaboration", where collaboration is obligatory in order to progress in the interactive experience. At the other end lies "enabled collaboration", where users can interact independently or collaboratively, resulting in the same degree of response from the system. In between lies "encouraged collaboration", where users are not obligated to work together, but they are motivated to do so, typically by the use of positive or enhanced feedback (see Figure 5.1).

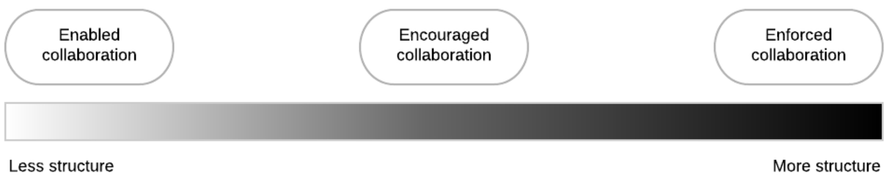


Figure 5.1: Collaborative systems may be classified based on the level of freedom or constraint given to user actions, resulting in more structured or less structured options for collaboration.

Enabled collaboration

Enabled collaboration occurs when users are capable of collaborating on a given task, although there are no added mechanisms, scripts or rewards when users choose to collaborate. This strategy can be seen as the development of scenarios for free collaboration, where users may decide to collaborate by their own volition, without incentives from the system.

In the Telltable project, users were provided with an interactive storytelling application and were asked to photograph everyday objects which served as inspirations for **narrative formation** [Cao et al., 2010]. In this type of **free play** systems, children form their own groups and draw upon their creativity to develop the game. Author observations indicated that the system empowered children to create their own stories, and also point out that external adult intervention was necessary for achieving proper collaborative outcomes. In 2009, Farr et al., proposed an enabled collaboration scenario through programmable tangibles that proved to reduce solitary play called Topobo [Farr et al., 2010]. The use of tangibles was intended to enable "computational offloading," helping children with ASD to understand other people's actions and intentions, increasing awareness of others' behavior, and authors reported that **limiting of resources** promoted interaction between participants.

In 2012, Hourcade et al. developed four simple multi-touch applications for tablet devices [Hourcade et al., 2012], which included a drawing application, a musical composition device, a puzzle game, and an application to distort images which helped children with ASD explore facial expressions. All the applications lacked specific internal constraints to control collaboration, but were rather led through **human mediation** and session guidelines.

	Human Mediation	Game Mechanics	Shared Goals	Joint Narrative Formation	Different User Roles	Free Play	Others Clear Visibility	Joint Actions	Limited Resources
Telltable	x			x		x			
Topobo						x	x		x
Hourcade et al. (2012)	x								
Sylla et al. (2013)				x			x		
StoryTable			x					x	
Collaborative Puzzle Game			x					x	
Block Party CVE								x	
Holt and Yuill (2014)	x		x				x		
Join-in Suite	x			x					
StoryMat				x					
Playground Architect			x		x				x
Pico's Adventure	x	x	x		x		x	x	
KidPad				x		x		x	
Klump						x		x	
SIDES		x	x						
Invasion of Wrong Planet		x	x				x		
Lands of Fog		x	x	x		x	x	x	

Table 5.1: Collaborative mechanisms implemented in related projects

Another enabled collaboration system was the tangible interface for collaborative storytelling designed by Cristina Sylla [Sylla, 2013], where children could practice **narrative formation** by arranging different blocks. A study with typically developing preschoolers revealed that the accessibility of tangible elements and **clear visibility** between actions in other children's stories made the platform successful in promoting collaboration between users.

Enforced collaboration

As collaborative activities become more structured, guidelines are layered which create enforced collaboration, which occurs when users are required to complete the activity by working together. The motivation behind enforced collaboration is that "by creating circumstances that inevitably demand collaboration in order to complete a desired goal, the child's brain will be required to generate and practice social skills" [Ben-Sasson et al., 2013]. Research has shown that in unguided scenarios, children with ASD tend to engage in parallel play rather than collaborative play [Bauminger et al., 2008].

In 2009 Gal et al., created StoryTable, used to motivate collaboration and social behaviors in children with ASD [Gal et al., 2009]. Children had to complete **joint actions** such as simultaneously touching a ladybug in order to choose a specific background or to listen to their taped voices. In the same year, Battochi et al. presented a similar solution, the Collaborative Puzzle Game (CPG), a tabletop system where collaboration was enforced through joint actions, as both users were required to move puzzle pieces in unison [Battocchi et al., 2009]. The enforced collaboration condition was more effective than a free play condition in eliciting simultaneous coordinated activity, but also increased the challenge of completing the tasks. Both systems required fine motor skills, which may increase the difficulty of the task for people with ASD who display patterns of repetitive stereotypical movements.

Millen et al. also utilized joint actions in the COSPATIAL research project, where they developed an enforced collaboration virtual environment called Block Party CVE [Millen et al., 2011]. In this project, users were required to move the same blocks in unison to achieve system goals, which reinforced communication.

Holt and Yuill presented an enforced collaboration application based on a separated control of a shared surface (SCoSS) where two users viewed a matrix which was used to classify objects [Holt and Yuill, 2014]. Both users had to do the same classification of objects and agree by simultaneously pushing voting buttons. The results showed that the system created more other-awareness when collaborating with a peer than with an adult partner, due to the **clear visibility** with regards to each other's actions.

Narrative formation can be seen in the Join-in Suite system, where users had to select between solutions to a social problem [Giusti et al., 2011]. The limited interaction space to implement an enforced collaboration approach led to dominant behaviors, in some cases calling for **human mediation**. Another storytelling application, called StoryMat, offered users the chance to create a story revolving around specific characters [Cassell and Ryokai, 2001].

Hendrix et al. presented the Playground Architect multi-player game to help shy children gain social confidence [Hendrix et al., 2009]. Enforced collaboration was based on asymmetrical **user roles**, assigning shy users the role of an architect and their peers as builders who followed instructions on a large electronic game board. During trials, shy children talked as much as their peers and enjoyed leadership. Although the asymmetric responsibility seems to properly address user limitations, it does also require screening of participants while preparing the sessions.

Encouraged collaboration

Encouraged collaboration is the method of implementing incentives for collaboration, while allowing space for individual play. As opposed to enforced collaboration, where users must collaborate in order to complete a task, encouraged collaboration allows users to adopt their own play style depending on how they want to engage in the game at that moment. This configuration aims to accommodate the varying dispositions towards collaboration shown by children with ASD through allowing space for children to reflect and ready themselves for socialization, and engage in collaboration when they feel comfortable to do so. In 2002 Benford et al., presented the KidStory technologies based on a Single Display Groupware (SDG): the KidPad, a shared drawing tool for **narrative formation**, and the Klump, a sculpting/modeling application to help children generate ideas in early stages of story development [Benford et al., 2000]. In the KidPad application, benefits in the form of unique colors were added for when children brought their digital crayons close to other players. Working with **joint actions** in the Klump, when certain buttons were pressed together, children could create novel combinations of materials.

In 2006, Piper et al. presented the SIDES DiamondTouch table game, designed to help adolescents with ASD practice group work skills [Piper et al., 2006]. The game was an encouraged collaboration interface, but with **system mechanics** to reinforce turn-taking and agreement, which prevented dominant players from taking control of the game and distributed responsibility evenly between users. Another system based on a multi-touch surface was the "Invasion of the Wrong Planet" hybrid game from Marwecki et al. [Marwecki et al., 2013], where the approach included rewarding multi-player actions more than solitary actions, and penalizing dominant behaviors. Both systems relied on interactive tabletops. This kind of small horizontal physical setting might limit other awareness, as users have to focus on a limited interactive surface losing vision of their peers with whom they are interacting.

A summary may be found in Table 5.1 of all reviewed articles and the different strategies adopted for motivating collaboration between users. The first section includes projects with enabled collaboration. The second section includes projects with enforced collaboration. The third section includes projects with encouraged collaboration. The two bolded projects, Lands of Fog and Pico's Adventure, will be discussed as case studies in the following sections.

In the following sections, we will present two full-body interactive systems made for collaboration of multiple users. We will then analyze the collaborative strategies implemented in each and discuss how these might have affected user behavior.

5.2.2 Case study 1: Enforced Collaboration

Pico's Adventure was a full-body interaction collaborative system developed for the European Commission research project "Motion-based adaptable playful learning experiences for children with motor and intellectual disabilities" (M4ALL). We designed the Kinect-based videogame to help young children with ASD learn and put into practice social abilities used in collaboration such as reciprocity (i.e. turn-taking), imitation, joint-attention and cooperation.

Practicing collaborative skills in the game was varied so children could use specific social skills in an incremental fashion over the course of four sessions. During the first session children explored to understand the extent of their control over the virtual environment while playing alone, thus avoiding a chaotic introduction to a virtual environment filled with multiple users. In the second session, children faced a problem they could not solve by themselves due to physical limitations, which required them to ask a parent for help. In order to complete the task, children were to ask parents to grab out-of-reach objects, embracing **user roles** to solve the problem.

During the third session, young children with ASD continued playing with their parent. Both were given a virtual laser "superpower" which extended in the direction they pointed and could be combined with the lasers of other users for extra power. The **game mechanic** was implemented to foster the use of pointing, a joint-attention behavior to share focus. The **clear visibility** of the other's superpower was meant to increase awareness of other users' actions and serve as a visual cue for helping children with ASD to practice joint-attention abilities. During the session, children employed **joint actions** to coordinate laser directions with their parents to

Figure 5.2: In Pico's Adventure, child with ASD and his mother collaborated by holding hands and collecting falling stars on their arms.

free trapped spaceships, requiring them to practice socialization (see Figure (see Figure 5.2).

Over the three first sessions children were introduced to all the skills necessary for the fourth session, in which they played with a peer with ASD. Users were required to join their virtual lasers again, this time with the **goal** of obtaining presents. **Game mechanics** were configured such that both children received a unique reward with each present, which they had to open through **joint selection**. The rewards served as positive reinforcements for children to solve each problem, and also as a measure of progress for the children during the session.

Methods

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 inclusion criteria was the following:

- Diagnostic for Autism Spectrum Disorder according to ADOS and ADI-R, applying DSM-IV-TR's criteria
- Cognitive capacity above 70 as measured by the Wechsler Intelligence Scale for Children (WISC)

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., 2001]). All participants met cut off scores for social interaction, communication and restricted and repetitive behaviors on the ADI-R. In order to estimate IQ, the Wechsler Intelligence Scale for Children-IV (WISC; [Wechsler, 1949]) was administered to children above 6 years old. Younger participants were administered the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; [Wechsler and Corporation., 2012]) or the Kaufman Assessment Battery for Children ([Singer et al., 2012]).

Materials

To evaluate the differences in social behaviors between the game and free play conditions, we recorded and video coded the sessions. The coding scheme observed social behaviors such as social initiations, requesting for help and responding to requests. This also took into account comments directed towards game characters, parents, the therapist, researchers, and peers.

The same video coding observational instrument was used for quantitative behavioral observation of the child with ASD 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. To evaluate the reliability between the four coder,s an initial training was performed until reaching an acceptable inter-rater reliability score (more than 80 per cent agreement) calculated through the Intra-class Correlation Coefficient (ICC).

Procedure

Each child played around 30 minutes during each of the four sessions. In each session children played with different partners.

The children also played in a control condition, which was a free play setting with different toys used by the psychologists during therapy sessions, such as cars, shopping products, puzzles or balls. Two experimental conditions were defined. In one children first did the free play session and later played Pico's Adventure. In the other condition children first played in Pico's Adventure and then did the free play session. Children were assigned to one condition or the other in a random order.

Results

Paired sample t-tests were conducted to compare the number of occurrence of target behaviors in the Pico's Adventure condition and in the free play condition. Results indicated that free play sessions significantly differed from Pico's Adventure play sessions (F (8) = 2.85; p = 0.00); thus relevant pair wise comparisons were performed to further understand the differences on social behaviors between the two settings.

In the sessions where children played alone with Pico's Adventure, a significant difference was reported in overall social initiations between Pico's Adventure sessions (M = 9.33, SD = 9.61) and the free play sessions (M = 4.08, SD = 3.82); t = 2.438, p = 0.033. A significant difference was found also when two ASD children were playing together in Pico's Adventure (M = 10.93 , SD = 5.54) and the free play sessions (M = 6.50, SD = 5.11);

t = 3.60, p = 0.003. Furthermore Cohen's effect size value (d = 0.962) suggested a high practical significance. Nonetheless, the sum of social actions did not significantly increase during the second and third sessions of Pico's Adventure when compared to the free play setting. In both of these sessions, children played with their parents.

When analyzing more specific social behaviors, we found a statistically significant difference on integrated requests when children were playing with their parents at the beginning of the second session. In this part of Pico's Adventure children showed a 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 = 2.839, p = 0.014. Cohen's effect size value (d = 0.80) suggested a high practical significance.

It is also relevant to note that in the design of the second level of Pico's Adventure there was an enforced collaboration scenario that was not successful in increasing the number of social behaviors. At the end of the second session, children were asked to grab hands with their parents to collect magic stars. As children were physically in contact with their parents, they substituted social behaviors for instrumentalization, or physically placing their parent into the correct position with scarce or no communication. Thus, they skipped social communication for physical use of their partner.

5.2.3 Case study 2: Encouraged Collaboration

Lands of Fog was a full-body interactive system created to foster social and collaborative behaviors in children with ASD. The interactive elements of the game could be activated through either solo or collaborative actions, depending on the nature of the element. For example, users began the game by collecting fireflies individually, which encouraged users to use the first minutes of the game exploring the scenario on their own to become familiar with the interaction dynamics of the virtual environment. Game mechanics and goals were never introduced to users, adopting an approach similar to **free play** scenarios.

Later, players acquired unique creatures which could interact and merge into two novel creatures when the players used **joint actions** to bring their creatures close to each other. Moreover, the players could decide to explore the digital environment together and interact with hidden virtual elements, whose animations could only be activated by both creatures working together. Discovering all different elements and creatures that populated the magical world would become a **shared goal** between users.

The use of individual and collaborative gestures in this game was meant to construct a hierarchy of activity, with collaborative actions building upon the interaction mechanics learned during individual play. The lack of structured guidance given to players was meant to encourage sharing of information and **narrative formation** between the children while playing. This created a community of practice through social sharing, teaching and imitation as the partners learned the game in unison.

Moreover, revealing extra game features through the use of collaborative actions was a **game mechanic** meant to encourage repetition of desired actions through immediate rewards, so that the children could see the benefits of working collaboratively and open themselves to continue playing with their partner. All visual feedback, from the color of the butterfly nets, matched by their collection of fireflies, to the fog holes and creatures that would follow users' butterfly nets, was not only meant to help children understand their own actions but also to have a **clear visibility** of others' actions during play.

One guiding principle in implementing encouraged collaboration in our system was the desire to create a comfortable environment for the children with ASD if they did not immediately feel able to open up to a partner within the exploratory format. This drew back to the goals of the game, which was to create a natural, spontaneous play experience where children with ASD could practice social initiation.

Methods

In a set of controlled laboratory trials, the system was tested with a total of 10 children with ASD between the ages of 10-14. The inclusion criteria was the following:

- Diagnostic for Autism Spectrum Disorder according to ADOS module 3 with a severity of 4
- Cognitive capacity above 70 as measured by the WISC

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 [Lord et al., 2001]. 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. As a measure to prevent problems playing or comprehending the game, the children with ASD and the typically developing 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].

Materials

The video coding scheme used for the 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 the video coding scheme from Pico's Adventure, which proved to be consistent for coding these social initiation behaviors. As in the previous project, we also evaluated the reliability between the coders. An initial training was performed until three coders reached an acceptable inter-rater reliability (more than 80 per cent agreement). As in the Pico's Adventure study, the reliability was calculated through the ICC.

Moreover, 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 player position and game events.

Procedure

Each child played for a duration of 15 minutes at a time with a different partner during three experimental sessions. Experiments were arranged through randomly controlled trials by changing the playing partner for each session in Barcelona. More information on the experimental trials may be found in Chapter 4.

Results

In the laboratory trials, children with ASD demonstrated a significant increase in the number of social initiations through the course of the three sessions ($Z = -2.810$, $p = 0.005$). We saw a significant increase of the amount of social acts from first session to third session ($Z = -2.807$, $p = 0.005$) and from second session to third session ($Z = -2.040$, $p = 0.041$). We also observed a significant increase in the number of responses made towards their typically developing partners (ANOVA: $F(2,9) = 8.049$, $p = 0.05$).

Children showed an increase in flexibility, from the first to the third session ($Z = -2.060$, $p = 0.039$), and an increase in activity levels reported by parents (ANOVA: $F(2,9) = 9.559$, $p < .05$), through the course of the sessions. Also, we observed a significant increase in the number of successful collaborative actions (jointly manipulating virtual elements) (ANOVA: $F(2,9) = 22.9$, $p < .05$). For a full explanation of results from laboratory trials, see [Mora-Guiard et al., 2017].

5.2.4 Observations

Enforced collaboration observations

By enforcing collaboration in Pico's Adventure, children with ASD engaged in social behaviors to solve a common problem rather than doing it in a solitary fashion or through parallel play. This follows with the proposal of Ben-Sasson et al., that if users must collaborate, they will have to put into practice cognitive processes related to socialization [Ben-Sasson et al., 2013].

When designing collaborative scenarios where users are enforced to cooperate, designers have the chance to specify the different actions users will have to undergo to achieve their goal. As previously mentioned, one way of controlling collaboration is through user roles. In the second session of Pico's Adventure, children with ASD had to search for tools to help the stranded alien. Nonetheless, the control granted to the children with ASD was constrained, thus obligating them to ask their parents for help. Yuill and Rogers proposed that one mechanism for constraint in multi-user collaborative interfaces is the degree of user control over the actions within the system [Yuill and Rogers, 2012]. Our constrained control design led users to naturally cooperate with their parents, which motivated them to explicitly ask for help, therefore putting into practice social skills.

Moreover, with Pico's Adventure we could see that enforced collaboration scenarios where users have the same roles and control might allow for lowering individualistic behaviors. In the fourth session, when two children with ASD had to play together, we did not observe dominant behaviors. Our observations are similar to those of Battochi et al. with the Collaborative Puzzle Game [Battocchi et al., 2009], where individual decision making was reduced through enforced collaboration. We only observed dominant behaviors when children chose to play through instrumentalizing their peer. In this case, as the game mechanic was based on the physical action of holding hands and moving in unison, children found a way to do without talking. Thus, it is important to reflect on ways in which children can avoid the desired behaviors, and the effect this might have towards achieving system goals.

Nonetheless, we observed that enforced collaboration scenarios give few chances for users to explore and learn how to interact with the system. As enforced collaboration revolves around precise paths of interaction, children have little chance to creatively explore how to approach the game in their own way. This can lead to a high level of mediation from the psychologist during the experimental sessions. In previous research, some authors advocate for the intervention of psychologists, parents or caregivers during the use of collaborative interactive systems [Boyle and Inmaculada Arnedillo-Sanchez, 2015, Hourcade et al., 2012]. Although one of the advantages of digital solutions is lowering the high time demand of human therapy for children with ASD, designers must reflect upon how to leverage the autonomy of the task so that it balances human intervention with technological intuitiveness.

Previous studies have noted that the use of joint actions might increase the challenge of a task [Battocchi et al., 2009, Ben-Sasson et al., 2013], which can lead to frustration by the users. In our case the potential frustration was mitigated through intervention of the psychologist and the control given to users. In Pico's Adventure, the interaction scenarios were based on digitally augmenting the capacities of the users, making the task easier because high precision was not required. The visual feedback also contributed in augmenting awareness of other users' actions, which we believed helped children with ASD to better understand and coordinate with their peer's actions.

Encouraged collaboration observations

Several notable patterns of behaviors emerged as a result of the encouraged collaboration format of the game. We saw the children with ASD becoming more open to collaborating with their partner in the later stages of play, as noted by the increase in collaborative actions such as activating virtual elements together. We believe that the coordinating visual and auditory effects served as a successful reinforcement to encourage children to explore these collaborative actions. That said, we also observed an increase in individual actions, so the increase in actions could be attributed to the children's process of learning how to play the game with fluidity.

The lack of structure and guidelines let children discover the system on their own, overlaying meaning and narrative creation into their actions. Through the sharing of narrations and expectations, children had an implicit path towards collaboration and a common ground for socialization. This resulted in a dialogue of propositions between the children as they discovered the hidden features of the game, creating unique emerging narratives as they played. For example, one child saw that his creature was changing color as he caught fireflies, and commented that his creature was eating the insects. Another child said that his creature was killing the fireflies, and yet another thought that his creature was leveling up with boosts from the insects. These emerging narratives were breeding grounds for reciprocal conversation as children debated the intricacies of the game. Therefore, encouraged collaboration might be especially useful for open-ended or free play settings where the designer's goal is for children to have the opportunity to express themselves, as opposed to following a set procedure of actions.

One possible pitfall of an unstructured game was seen when a single player became dominant or individualistic during play. To prevent this, space must be left for expert mediation in the form of monitoring by a tutor or researcher. In intervention scenarios, it might also be beneficial to screen and match users with compatible personalities and levels of activity.

Instead of requiring the children to work together, we wanted to entice them to socialize by providing ample opportunities for engagement while playing. These opportunities came in the form of surprising and exciting elements hidden in the game that the children could share with their companion upon discovery. In this sense, just as wearing a colorful necklace can serve as a conversation starter, the game sparked initiation between players through attention catching features such as amusing creatures and object animations. For example, when creatures successfully activated a part of the scenario, they would do a lively victory dance. One inspiration for this technique came from the ECHOES virtual environment, where it was found that unexpected responses from the system were successful in sparking reactions from the children with ASD [Alcorn et al., 2013].

To fully take advantage of the system's affordances in play construction, children might benefit from exploring the range of interactions in an incremental and introductory manner. For a simple object like a ball, the affordances might be readily understood: bounce, toss, roll, etc. However, in more complex systems, users might benefit from an exploratory period where they are led through the various possibilities of the system and understand how simple mechanics can be combined into more complex ones. Correspondingly, in Lands of Fog, the users first learned that butterfly nets indicate their path of movement in the game through openings in the virtual fog, and users later used this path to capture and incorporate virtual fireflies into their personal zone of activity. In this way, structured mechanics can give information to help orient players without obligating them to follow a strict procedure.

Consistent with other systems which offer the option of solitary actions, we noticed that some children became more absorbed in individual play instead of working together with their partner. In an extreme case, one boy evaded contact with his partner in order to avoid a form change in his own creature, which was implemented as a collaborative action. This interesting feedback of changing textures, which was meant to spark the curiosity of the children, worked against the goal of collaboration in that particular case because the child had become attached to his creature. This same mechanic was seen as a positive feature for other children who were interested in exploring the range of possible creatures in the game, thereby collaborating to change their creature with the help of their peer.

One way to dissuade isolated play might be to utilize the game space characteristics. In Lands of Fog, we designed a circular arena to create a natural flow of movement towards the center, eliminating the possibility of hiding in corners. This structure allowed for serendipitous encounters between the children as they navigated through the virtual scenario.

To respect the varying dispositions towards collaboration shown by children with ASD, encouraged collaboration takes into account the variability of attitudes and moods of players by allowing the space needed to set the pace for their own style of learning. Therefore, players are able to take the steps towards socialization when they feel comfortable to do so, which might help contribute towards a positive experience for players. Still, more research must be done to identify the emotional and biological response that arises when children with ASD interact with others during playful experiences.

5.2.5 Implications

In this section, we have discussed methods for structuring collaboration through digital environments, using relevant examples of our past work on collaborative systems for children with ASD. As children with ASD show tendencies towards solitary play, designers must consider ways to make collaborative play appeal to this user group. The ideal system would present these collaborative moments as positive experiences for the children with ASD so they might be more willing to try working with others in classroom or playground scenarios.

Given the information discussed in this paper, we have presented a list of preliminary observations for the efficacy of these methods in interactive systems. From the reviewed articles and the analysis of our own systems, the following guidelines might be useful when designing collocated collaborative interactive systems for children with ASD:

- **Human mediation** can be implemented as a way of balancing input and unexpected behaviors from users. Care must be taken to leverage the amount of human mediation and system autonomy which is necessary. This can be based on the setting in which the interactive system is going to be used, and the designer's will with regard to increasing structure of the system.
- Testing the experience can be valuable in properly understanding when designed **game mechanics** are interpreted by users differently from the designer's intentions, and how these unexpected interpretations can open or jeopardize opportunities for socialization. Designers

might choose to embrace the physical affordances of the system to promote mechanics such as joint actions and shared negotiation. Also, designers may choose to take into consideration the skills and limitations of the user group when designing **joint actions**, in order to avoid frustration.

- Having specific feedback that helps users to understand not only their own actions, but also the actions of others, will help build a common knowledge of joint activity and their consequences, also helping users understand which collaborative actions they must do together to achieve their shared goals.

- Giving users basic content which is flexible to changes may be useful to build a common understanding of the system, which can lead to greater social communication as both users **form a narrative** from their shared experience.

- Assigning **user roles** can be done by reflecting upon the capacities and limitations of each user, thus allowing for a more natural emergence of the participants' special characteristics in the experience. Also, configuring the amount of **limited resources** provided can increase player interdependency, leading to moments such as asking for help or negotiation of tasks.

- Designing for a play space that embraces different game flows and learning styles may contribute to a more natural user experience. Moments of **free play** can be used to give users space for reflection allow interactive freedom for them to adopt individual playing styles.

It must be noted that, although studies have compared free play versus enforced collaboration settings using different systems, more research must be done in the form of controlled studies of the same system varying along the gradients of collaboration, in order to truly understand the behavioral tendencies, comfort level and complexities of socialization fostered by both conditions.

As discussed, measuring collaboration is typically done by assessing completion of a certain task. However, as Regh, et al. noted [Rehg et al., 2013], social interactions might not be measured best by the performance of a particular task, but should rather be defined by the degree of the reciprocity between engaging participants. Therefore, when evaluating collaboration in children with ASD, we must take into account the nature of social interactions that take place during the task and whether these contribute to a positive experience.

5.3 Open-ended Play

Adapted from the article *Design and Evaluation of a classroom adaptable open-ended play environment to support social interaction in Autism.*

This section will discuss the development and evaluation of the system GenPlay as an open-ended collaborative activity to encourage collaborative play among classroom members of varying cognitive abilities. First we will discuss what open-ended play is, then introduce a set of design cards which were created for the design of open-ended play systems. Taking the ideas presented on the cards as a guide, we will then discuss the interaction design of the GenPlay system in the open-ended Play Lens. We will then present the results of an experimental study with the GenPlay system, and discuss how the cards might be used as a posterior evaluation tool for identifying and classifying social behaviors. It is important to note that the cards were not used in the design on the GenPlay system, but rather during posterior analysis. We would like to introduce the idea that the cards are not only a useful tool for design, but also for evaluation and reflection of systems.

The GenPlay virtual environment was designed to encourage collaboration between class members of mixed abilities through exploration of a virtual environment. The interaction relies upon open-ended play to support opportunities for socialization. For more information on the design process of GenPlay, refer to Chapter 4.

The evaluation of the project was based upon a deck of design cards called the Lenses of Play [Bekker et al., 2015], which were created to help designers and design students in the creation of playful systems. The deck divides cards into four categories, or lenses: Stages of Play, Forms of Play, Emergence Principles and Parameters, and Open-ended play. The present work will discuss which decisions were made to support open-ended play in the interaction design of the system and how we expected this to produce collaboration. In the end, we will reflect on these same decisions to respond to the hypothesis of the project: The open-ended design of the system will support social interaction.

The contribution of this section is twofold. In addition to presenting the process of design and evaluation of an open-ended play system for autism, the secondary contribution of this section is the use of open-ended play items as a framework for design reflection. This will be done in two phases. First, we will review the interaction design of the system, basing it upon the needs of children with autism. We will pay particular focus to the decisions made to foster socialization through open-ended play, using the terminology proposed by the lenses of play design cards. For each decision made in the interaction design of the system, we will describe the result that we anticipated, i.e. how it would foster social play. We aim to answer the question: How do the technical properties of the virtual environment influence the children's play experience with peers?

The second phase of analysis will be based upon the data collected from an on-site study with a mixed abilities school. Through this data, we will discuss what we saw, what we expected but did not see, and what we saw that we did not expect. We will reflect on these results using the categories proposed in the open-ended play items from the Lenses of Play card deck. In the discussion, we will observe strengths and weaknesses in using the lenses of play cards as a framework for to interpret the behavior of users in the interactive system.

5.3.1 Background

In the design of play based interventions for autism, one of the most recognized examples involves the use of LEGO building blocks as a medium for motivating social interaction [LeGoff, 2004]. LEGO play therapy works to develop skills such as joint attention and social interaction through shared building tasks. These therapies can be adapted for both individual and group therapy settings.

Within the practice of play therapies, we can also find approaches such as DIRFloortime [Hess, 2013]. This approach relies upon the DIR model, which stands for The Developmental, Individual Difference, Relationship-Based Model. The model is flexible in its application in intervention practices involving various conditions, and has been used to work with building relationship skills in children with autism by focusing on individual needs and skills relevant to developmental stages. The model is unique in its reliance upon exploratory and open-ended questions and play activities between parents, therapists, and children, fostering skills such as joint attention.

Open-ended play

Open-ended play does not occur in isolation, but rather as part of a spectrum. In describing the continuum upon which play and games are situated, Callois defined the end of the spectrum with highly structured activities such as games as Ludus. At the other end is Padia, which includes free play activities based on spontaneous sensations, such as spinning or skipping [Caillois and Barash, 1961]. Open-ended play can occur anywhere between these bounds. A defining characteristic of open-ended play is the absence of highly structured rules or goals, as players have the chance to create these on their own rules and meaning as they play [de Valk et al., 2015].

One benefit of open-ended play is the inherent propensity to provide socialization opportunities, as players develop a personalized play experience. Conscious exploration of the play setting leads to the sharing of discoveries between players. A minimum level of ambiguity creates a space for players to assign their own meanings to the effects encountered. Less structure often leads to more individual choice as to the playing style which users embrace. In the negotiation of rules and goals between players, these systems present ideal moments for socialization.

Lenses of Play cards

Open-ended play is valuable in its propensity to provide flexibility in developing one's own play activities, leading to opportunities for socialization between players. In the case of children with autism, who have significant challenges in social and communicative behaviors, interactive systems can provide opportunities to scaffold socialization and collaboration with others. In searching for strategies to support these behaviors, we turn to a deck of design cards created to help designers develop playful systems using open-ended play. These cards allow designers to phrase different ways for developing playful systems.

The Lenses of Play cards were developed at the Eindhoven University of Technology, and are intended to help designers and design students develop systems which embrace a playful perspective. The intended application is to convert implicit knowledge used in the design process into explicit knowledge to be reflected upon and discussed openly.

The cards were developed specifically to help with inspiration and reflection during the design phase of projects. The ideas presented in the cards were derived from values found to be useful in motivating playful interactions [Bekker et al., 2010], [Bekker et al., 2008], [De Valk et al., 2012]. Previous work involving the cards has included analyzing their reception among design students [de Valk et al., 2013] and utility in making detailed design decisions. However, post-experimental evaluation and reflection is a novel use of the cards.

Four categories are presented within the deck: open-ended interactions, stages of play, forms of play, and emergent behavior, along with a card of instructions for use. The instructions card recommends that designers select one or two cards per category during project synthesis. This article will deal specifically with the open-ended interactions cards, in which six ideas were presented. These cards will be described individually as design concepts in the following section.

5.3.2 Case study: Open-ended play for ASD

The system consisted of a circular floor projection which could adjust to the dimensions of a classroom space, up to a maximum size of 2.5 x 3 meters. As children moved across the floor projection, their movements and gestures were detected by a Kinect sensor. The game design was a black background with white rings of random sizes that responded to the movements and actions of the children as they moved. The following section will describe the interaction design of the system based on the open-ended play concepts found in the Lenses of Play card deck.

Ambiguity: Ambiguity can be seen as leaving parts of the game open for players to fill in with their own ideas. Perhaps designers might choose to use shapes or audiovisual effects which can inspire different perceptions or lead to the formation of rules. By using ambiguity, designers do not provide all of the answers for the users, but instead let users develop their own insights based upon a basic structure. In GenPlay, we chose to use abstract visual elements such as circles and squares. Instead of using recognizable elements like human or animal characters, we intentionally kept the design simple and built up the complexity with generative effects which would divide geometries or multiply. Our design intention was for the abstract design to invoke subjective perceptions by users as they played.

Imagination: The concept of imagination builds upon that of ambiguity, in allowing children to build their own stories. With ambiguity, children can see and create observations based on their own interpretations. With imagination, these interpretations can be strung together to create a narrative or tale which characterizes the player's experience and perceptions.

Although children with autism have difficulties with symbolic play, we saw that they did possess creative thinking skills during the participatory design sessions. Our goal was to pull out their creativity with interesting and engaging audiovisual effects.

In the first prototype of our system, we created a system which generated a shark character when players got close to each other. The shark emerged from between the children's feet and swam through the play arena. Later, we converted this shark to a yellow orb which kept the same interactions. We wanted to see how children would overlay their own meaning for the behavior of this simple object that had lifelike characteristics. Therefore, our design intention was for the yellow orb to inspire the children to create stories to give life and meaning to the elements.

Negotiation: Negotiation occurs when players work things out through conversation. Players can also negotiate when agreeing to work collaboratively. We saw that negotiations often happened as players took turns trying different strategies for replicating audiovisual effects, to discover how the system worked.

In our system, we designed for negotiation with single player and multiplayer interactions. As children with autism have difficulties with social initiation, we used proximity as a tool to draw users together into the same space, creating settings optimal for social moments. Once users were close, we built upon joint attention by using joint actions which players had to negotiate to complete. After coming close to their partner, a yellow orb was formed. These yellow orbs could be stepped on by one player or both players, to create a particle explosion with various colors and shapes (see Figure 5.3). The color, shape, and behavior of the particles was randomized to allow for many possibilities for discovery, but the size of the explosion was related to how many users triggered it. A single user could step on the orb to create an explosion, and the explosion was much bigger if both users stepped on the orb together. The difference between these effects was meant to encourage collaboration between players as they negotiated to get the large explosion effect.

Figure 5.3: Yellow orbs created large particle explosions when stepped on.

Another interaction which differed between single player and multiplayer use was found on the colorful effects which formed a halo around the player's feet as they moved. This marked where users were stepping in the system, and created a larger imprint for interacting with other elements projected in the scenario. As players walked, their feet left large imprints like elephant feet, and they could get close to other players to merge their foot markers. The foot markers, or metaballs, changed their shape when players put their own two feet together, and changed color when a player stepped on the foot marker of another player (see Figure 5.4). This was a subtle way to encourage players to collaborate and negotiate the exploration of different combinations.

Freedom of Interpretation: Designers normally provide an underlying structure in interactive systems, even when designing for open-ended play.

Figure 5.4: Foot markers formed a halo around the children's feet as they moved and could interact with the environment or be merged with those of other players.

This can come in the form of designing objects with affordances which lead to certain actions. For example, a tennis racket is designed to be held at one end, as indicated by the soft grips wrapped around the base. However, it is up to users to decide how these objects are to be used, and how to implement the affordances provided by designers. In the case of interactive systems, users might define gameplay patterns that differ from those envisioned by designers. The freedom for users to interpret rules can lead to social opportunities, as users externalize and spontaneously develop ideas for play. In our system, after deciding that the goal was socialization between classmates, we then proposed and tried many interactions which we believed would lead to this goal. However, it was also ensured that there was not only one way to play the game, and that the game would continue even if players did not follow a single path of exploration.

Semi-structured: Similar to the previous item, children go through a process of discovery and deciding their own rules as they explore the features of an open-ended play system. However, as the play becomes prolonged, these rules sometimes change or are extended upon to make room for new ideas. The flexibility of a system to accommodate changes in play as new information is gathered is part of determining its level of structure. Elements of structure also include rules, goals, and order of actions. With our system, we decided that the system should have an underlying activity, or a life of its own, regardless of how children were interacting. We did this by creating light rings which appeared and drifted through the scenario in random shapes and sizes. For the designers, these rings were like raindrops, and could be kicked to create small explosions or divisions. The number of rings multiplied based on player proximity. If the players were at opposite ends of the play space, almost no circles were present. As players moved closer, the number of circles present in the arena incremented. This was a subtle feature designed to give a background structure to the game and provide a setting for other interactions to take place.

Diversity: The diversity of a system can be understood in terms of the various forms of play supported. The Lenses of Play card deck dedicates a section to these play forms, in which five concepts are presented: constructive play, pretend play, physical play, social play, and games with rules.

In designing our system, we observed the children with autism engaging in physical play on the patio of the special needs school, where they would collaborate with their peers in active play involving running and carrying blocks. Therefore, we used physical play as a means for engagement, envisioning the children chasing the yellow orb particles as they moved in unpredictable paths through the scenario. We also implemented different audiovisual effects for physical interactions such as jumping, stomping, and pushing the bubbles. Once music was added, the tempo of the music increased with the movement pace of the users.

During pilot trials, we saw that some children crouched down and tried to interact with the projected surface with their hands or whole bodies. In order to support this exploration with various forms of physical play, we also configured the tracking system to detect users when they sat or laid down on the floor, in addition to when they were standing.

Designing for social play was one major objective of the system. However, we did not want to put the children with autism in a situation where they would be forced to interact with others. Therefore, in addition to implementing collaborative interactions when users worked together, we also left players space to play individually if they wished. To do this, we created a diversity of interactions which would respond when players played individually (glowing footprints, bubble divisions and explosions upon stomping) or collaboratively (getting close to create drifting yellow orbs, popping the orbs together). We viewed this paradigm of giving players space to work alone, while positively reinforcing collaborative behaviors, as encouraged collaboration [Crowell et al., 2019].

5.3.3 Methods

The GenPlay system was tested over the course of two days at a mainstream school in Netherlands, which also catered to a small number of children with autism. Participating in the study were two classrooms and a total of 57 children between 10-11 years old. Two of the children had autism and were integrated into the same classrooms and instructional activities with peers without autism.

Researchers met with the teachers to define the experimental protocol and select the best area to conduct the trials. The two teachers adopted various forms of technology in their daily teaching activities, and were interested in trying the system with their students. It was important to choose an area that children were familiar with, to see the system as part of their own environment. It was decided that the system would be set up in a multipurpose room where children routinely attended music class.

On the first day, children entered the room with a partner and their teacher, and played the system in pairs for sessions that lasted four minutes. The children were instructed to explore the system and share anything interesting they found with their partner. On the second day, the whole classroom came to the room together and two children at a time played the system for four minutes per pair. The other members of the classroom were encouraged to participate from the sidelines. The game tested on the second day varied slightly in visual design and added sound effects. This difference was intended so that players would continue their exploration of the system over the course of both days. Afterwards, players were asked for verbal feedback on the game.

In addition to verbal feedback, data was collected through video recording the sessions. Video documentation was translated to English by a native Dutch speaker. Then, each video was reviewed to see how the children had engaged in social behaviors while playing the game. Behaviors which were prompted by the open-ended play concepts were tagged following the lenses of play categories. We then reflected on how the resulting behaviors had differed or aligned with our design intentions. These reflections are presented in the following section.

5.3.4 Observations

Ambiguity: In designing for ambiguity, we expected that the abstract design would invoke different perceptions by different users. A few children overlaid their own meanings onto virtual objects, comparing them to real world objects. One child looked at the large circles around his feet and said "It looks like cells that split and get back together." In reference to the design of using basic geometric shapes such as circular white rings, one child with autism remarked "it looks like a big bubble bath with a few large bubbles." Later on, when the same child struggled with understanding the game, he exclaimed "stupid bubble bath!" It is important to note that, of the 57 children who played the game, only two children voiced frustrations on how the game "did not make sense." These two children were the only participants with autism.

Imagination: As we aimed to scaffold the children's imagination, we anticipated that the lifelike behavior of the yellow orb would create interpretations of lifelike elements, that would later form the basis of stories. In observing the children's play, we saw that the children did not interpret the orb as a lifelike element, and instead referred to it as a button. This was probably due to the interactive qualities of the orb, which presented an explosion of particles when children stepped on it. They also interacted with it like it was a button placed on the floor, by jumping onto it and waiting for the reaction. In one play session, a child told his partner "I pushed the button." When another orb appeared, the child said "there is a button here!" When an orb floated out of reach of one child with autism, he stood still and instructed his partner to get it: "If you push that button, it goes away." Then his partner ran to catch the yellow ball. This reference to the orb as a button was seen in multiple sessions.

We were interested to see the stories that children would create from their own imagination that we could not anticipate, as they developed meaning through the play experience. We observed children creating stories based on the context of the virtual environment. One child remarked of white orbs floating through the environment "it looks like we are on an assembly line, or a conveyor belt." The child stood on a yellow orb and said "I am keeping it under control," and pretended to monitor his conveyor belt. Other children assigned lifelike behaviors to the virtual elements. For example, when one child's foot outline stayed in one place, he said "it is not following me."

Negotiation: We designed for the children to negotiate through collaborating to achieve multiplayer effects. Some kids commented on the color change in their footprints when they got close, and negotiated to change it together. One child commented "Look, if you stand together, it gets red!" Then he went to his partner to try it. The other child said "Come here. Let's get closer so we can change color."

The particle explosions caught the interest of the children, and they commented on them to their partners. When one child achieved an explosion, he pointed it out to the other player and said, "Oh look!" When a big explosion came from working together, a child exclaimed "Oh, this one is

EXTRA big!" The children seemed to notice the larger explosion size, although it was not clear if they understood that working together caused the larger explosion size.

Negotiation also came as kids discussed why some yellow orbs moved and others did not. As they did this, kids followed the orb and talked about the discovery of popping it. One child commented, "Maybe it works like this: maybe it only goes in the dark shadow, or this ball has to be on it." Then he tried to touch the orb and said "Maybe you cannot reach it if bubbles come on top."

We also found that an error in the game also led to communication between players. When one yellow orb got stuck on the side of the arena, a child remarked, "Why doesn't it work?" The children discussed possibilities then later the child shouted "Yay, I hit the one that could not be reached!"

Freedom of Interpretation: In designing for freedom of interpretation, we intentionally left some parts of the game open for children to create rules which differed from our design estimations. In chasing the yellow orbs, we saw that some children competed to get balls, and others collaborated by helping their partners find them. We also saw that children created their own game from trying to collect as many orbs as possible. For example, as one kid jumped to reach an orb, he said "You have to get yellow balls!" Then he started counting "here, here" with every orb he reached.

Other children created their own rules for play which differed from the designer's rules, through differences in interpretation and errors in understanding of the game mechanics. For example, one child said "Only if the balls move, they explode," which was not really true. Later, his partner questioned "Why doesn't it work?" The classmate responded, "Because it does not move." Actually, the child was not standing directly on top of the orb, so the system did not trigger the activation mechanic. Another kid told his partner "You popped it (yellow orb) because you were standing still." This was part of learning how the game worked.

Semi-structured: As they learned to play, children explored different possibilities in the game and changed playing style. We saw this particularly with regard to the large footprints which were projected onto the children's feet (see Figure 5.5). At the beginning, many children shuffled their feet along the floor, trying to drag the foot markers, before learning that the markers followed them regardless. One kid moved feet together and apart and said, "Oh, the bubbles move with you!" Then his partner imitated the movement, and hovered his foot over the floor, saying "Oh, you can hit it without stepping on it!" Then he jumped around on 1 foot. Another child, upon discovering this, said "Oh, that is much easier than sliding." From this discovery, we saw a variety of interactions. One child asked his partner "What happens if we stand with 1 leg in [the other's footprint] and the other out?" Then the two kids tried it together. One kid commented, "If you spread your legs, they come apart. Cool, right?" Later, he said "If you jump, it stays in the same place," and took a few steps jumping.

Figure 5.5: Children explored various interactions as they learned that foot markers moved with them.

Diversity: We designed for the children to embrace diversity in playing forms such as physical play and social play. We saw a high level of physical play as children competed to explode yellow orbs, pushing each other out of the way because they did not know that collaboration would result in bigger explosions. One child told his partner "Yay I have one!" and the partner replied "I am going to steal it!"

The children also engaged in physical play when they learned that their footprints changed color when close to a partner. When one boy saw that his footprints were turning red, he started following his partner. His partner then pushed him away and said "Go away, go away! You have your own!" The partner pushed him on the ground, where the two boys wrestled. Other children ran to see if their footprints followed them, or tried different playing positions. One kid got down on his knees and scooted, while the other crouched down. One child held his knee in his arms to balance on one foot, then took big steps like a giant. "Hey, look at this!" he said, jumping with both feet, before sitting down to rest.

With regard to social play, we observed that the children switched between individual and collaborative play, especially at the beginning as they explored the scenario (see Figure 5.6). In one session, the two children started moving together, walking in parallel, then one kid went to chase an orb, then the other asked to come back together. Later, the children walked separately and talked to share their findings. This switching between play modes was common for the duration of the scenario, as children explored and shared their discoveries.

We also saw that the children engaged in pretend play. When one particle explosion occurred, a child threw his hands in the air, saying "Ahh!" and jumping back from a pretend impact. Pretend play was especially frequent when the classmates were present, as the arena became a stage for performing acts and showing off dance skills. As one girl entered the scenario, the children on the sidelines asked her to "pretend to be a ballerina." The girl responded by putting her hands above her head and spinning in a circle. When a boy entered, a group of peers on the side yelled "Do the worm!" and the child got on the floor to perform for his peers. The player then asked his partner to move and performed a cartwheel. The kids on the side, inspired by their peer's reaction, then asked for the child to "Do the ninja skills!" The player then did a dance, leapt to put his foot on his partner's orb, then did a half-split. The children on the side then said "Do the eagle!" The player waved his hands in air and moved his feet below, as kids on side imitated the behaviors to each other. It might be relevant to note that these

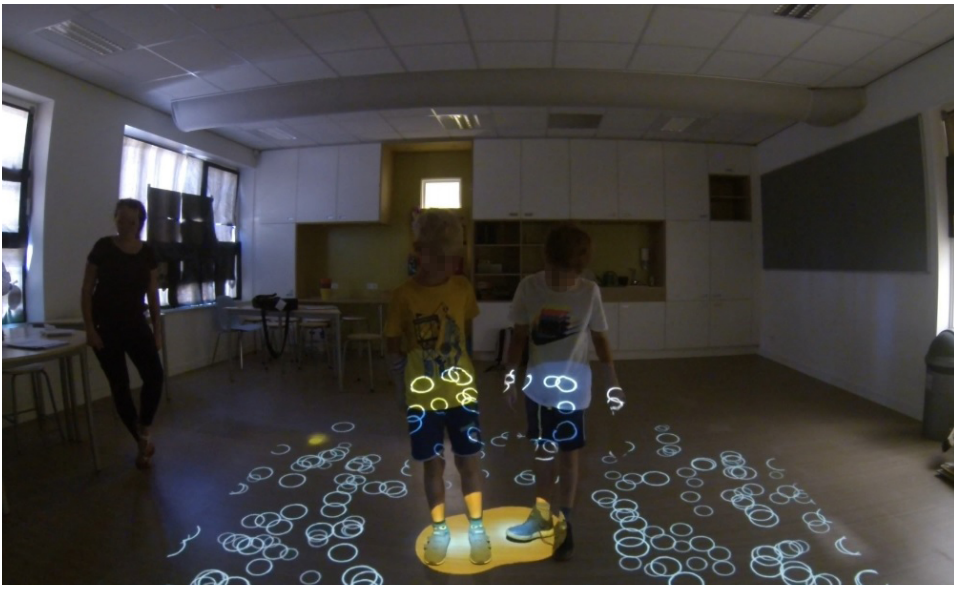


Figure 5.6: Children switched between individual and collaborative play, and pairs frequently began sessions by standing close together in the middle of the environment.

trials took place during the last week of school before summer break.

5.3.5 Implications

We will first form the discussion around the reception of the open-ended game by the children with autism in the classroom. Then we will discuss the utility of the open-ended play cards as a tool for behavioral analysis.

Autism and ambiguity

One of the most interesting results was the large gap in tendency to search for purpose in understanding the game that was present between the children with autism and the typically developing peers. During post session interviews, one child with autism remarked "I thought it was fun and nice. At first we didn't know what to do, then we had to get yellow balls." The other child with autism who participated in the trials directly commented

"I really did not get this game." The typically developing children were more likely to comment that the game was fun or cool. It would also be fair to suppose that the typically developing children also did not understand the game, but their comments did not indicate that they were trying to find a deeper purpose. In fact, the purpose of the game was for the children with autism to have a positive play experience with classmates, in an environment which is suited to their interests and sensitivities to audiovisual stimuli.

With regard to this, the child with autism had spent the majority of the game engaged in social play with his partner, and was very actively engaged in showing his partner his discoveries as they explored the game. The teacher of the same child remarked that she had not seen him so happy during the past year as when he was playing the game. Therefore, the game did elicit a social play experience. However, the child was at least somewhat confused by the open-ended nature of the game, specifically, the ambiguity and lack of goal. As activities made for children with autism suggest detailed instructions to guide the activity, more guidance might have led to a better sense of orientation for the child while inside the virtual environment. More research should be done to understand how these instructions can be given while maintaining a semi-structured nature for the children to fill in with their own creativity.

Teacher presence also played a large part in scaffolding social behaviors and engagement in the game, both in the experimental trials and during the design workshops. Previous work has highlighted the external role which the researchers play when they have not been integrated into classroom activities for a long duration. It might be speculated how teacher guidance could provide the orientation that children with autism need while playing open-ended systems, and how this could also alter their one-to-one experience of discovering things together with their class peer.

Recommendations for Lenses of Play

This analysis is the first time that the Lenses of Play cards have been used as a tool for reflection and post-testing categorization of behaviors, as they were intended as a design tool. Thinking back through the design intentions during the evaluation phase helped to refresh on the original purpose in developing the system and how we sought to achieve it with the design choices made. Here we suggest a few adaptations in their structure and implementation as an evaluation tool.

Our understanding of the cards changed from pre- to post-analysis, as we were first viewing the cards as a design tool and afterwards as a categorization of behaviors. For some concepts, it was difficult to categorize and anticipate behaviors that had not yet occurred. This was especially true for the Freedom of Interpretation and Imagination cards. We used the Freedom of Interpretation card to represent the differences in understanding the game between the designer's vision and the player's vision. When one reads the nomenclature of Freedom of Interpretation, it might be confused with the function of the Ambiguity or Imagination cards, which we used to represent children's interpretation of the game elements and how those interpretations flowed into stories.

Working with the cards during the post-game analysis, it seemed as if the six cards naturally arranged themselves into 3 groupings: Interpretations (Ambiguity, Imagination), Rules (Negotiation, Freedom of Interpretation, Semi-Structured), and Diversity.

Semi-structured was the most challenging card to use due to its broad definition, which seemed to fit more in terms of game elements, whereas the other cards related to the type of play engendered. Diversity was the easiest card to use, as it was facilitated directly by another set of cards in the deck. It seemed as if Negotiation was the broadest category, as many negotiation behaviors could have crossed into other categories. For example, children tended to negotiate most in order to understand rules, which could also fit into the Freedom of Interpretation category. Children also negotiated when engaging in social play. Therefore, it might be possible that these categories are not fit for distinct categorizations in their current form, but might rather serve as useful tools for reflection.

Using open-ended play in working with social play in a classroom setting does seem to be a valid approach for eliciting socialization; however, designers should be consistent in the guidance provided. Leaving the children to discover the game on their own might be too disorienting for children with autism, as we saw some express confusion when searching for a way for the game to make sense.' As open-ended play is continuous in the level of structure included, perhaps providing clear feedback would shift the design more to the side of structured games. This study leaves the path open for future research which focuses specifically on playful meaning-making in autism and the routes to which an interactive system can scaffold this while leaving room for open-ended play with peers.

5.4 Proxemics

It is a common sentiment to ponder how it would be to walk in someone else's shoes for a day. Similarly, in the study of human-computer interaction, designers try to understand the use of interactive systems through the eyes of our target user group. However, challenges arise when approximating the desired use of interactive systems for target users who have alterations in cognitive functioning.

Interpersonal distance is defined as the area which we choose to keep between ourselves and others, revealed through observation and cultural components. Although previous studies have suggested the possibility of alterations in perception of interpersonal distance in children with Autism Spectrum Disorder, it remains unknown whether these differences exist in relation to characters in a virtual environment. As many social-skills interventions for autism rely upon virtual characters to teach social behaviors, this research is key in understanding how to configure the interpersonal distance of virtual characters to an adequate level to effectively foster computerized social-skills training. We have carried out controlled trials with children with autism to identify variations in preferences from the typically developing population with both a human partner and a virtual character. The contributions of this research are twofold: first, to support existing literature in identifying differences in personal space preferences between children with autism and typically developing children; and second, to understand whether these differences carry over into the context of virtual environments. We saw this study as integral in determining the relevance of the interpersonal distances embraced in the Lands of Fog and GenPlay systems, to better understand if these are consistent with interpersonal interactions outside of the virtual environments.

Individuals with Autism Spectrum Disorder perceive the world in a unique manner which reflects the nature of their condition. The field of research which focuses on Autism has identified three main characteristics which contribute to this particular perception: communication challenges, a tendency to engage in repetitive behaviors, and social-interaction difficulties. The differences which pertain to this condition shed light on the manner in which these individuals may interact with information and communication technologies, an area of heightened interest for children with ASD. With respect to social-interaction difficulties, much research has focused on creating collaborative scenarios for practicing and strengthening social capabilities in these children [Mora-Guiard et al., 2017]. However, these projects have not considered how interpersonal distance specific to ASD could be utilized as a way of fostering social behaviors between users. As proxemics theory has been implemented in interactive systems as a way to understand device to people relations [Ballendat et al., 2010] and social interaction between typically developing users [Mueller et al., 2014], we believe this work could be valuable in the design of interactive systems for social intervention in children with ASD.

Our aim with this research study was to identify particularities in the perception of personal space with virtual agents for a specific user group, namely those with Autism Spectrum Disorders. Ultimately our aim is to contribute to the creation of interactive systems through a better understanding of personal space preferences for a target user group, in real life and virtual scenarios.

5.4.1 Background

Interpersonal distance is present in each interaction which we conduct face-to-face with others. Although largely subconscious, these distances become evident as we orient ourselves towards others in social situations, typically in four distinct zones: intimate space, personal space, social space, and public space. Cultural differences in interpersonal space preferences have been observed through the study of proxemics [Hall, 1969], along with differences related to age, sex, personal traits, and nature of the relationship.

In an experimental setting, interpersonal distance is often tested through the use of a stop-distance test. This simple but widely-recognized test involves one subject remaining stationary at a designated point as an interlocutor gradually approaches by walking head-on [Hayduk, 1978]. When the subject feels as if the interlocutor has reached the edge of their comfort threshold, they make a signal, often by saying "stop." This test has been used with children with ASD to detect personal space preferences before and after socializing with an adult confederate [Gessaroli et al., 2013]. When compared to typically developing children, the children with ASD preferred a slightly greater distance between themselves and the adult confederate.

Personal space preference may also be detected through naturalistic observation. In an experiment by Rogers and Fine [Rogers and Fine, 1977], a child with ASD and a child with symbiotic psychosis were observed for preferences in personal space during play therapy sessions with a therapist. Observations revealed that the child with ASD preferred a significantly greater distance between himself and the therapist than the symbiotic child.

Proxemics in computer based systems

An early mention of possible inconsistencies with proxemic perception in children with ASD came when Parsons created and tested the Virtual Cafe system, an intervention tool for social skills in which children experienced simulations of real-life scenarios such as finding a seat on a bus or navigating through a cafeteria [Parsons, S., Mitchell, P., & Leonard, 2004]. In this system, it was observed that the children with ASD bumped into virtual characters representing people, a behavior which differed from the typically developing users. From this arose the question of whether children with ASD might have impairments in personal space preferences, and particularly in relation to virtual characters.

In addition, Welch et al. detected the response of children with ASD to various measures of social distance and eye gaze of a humanoid avatar in a virtual environment [Welch et al., 2010]. Children with ASD seemed to show unusual reactions to the avatars when standing at an invasive distance or using increased amounts of eye contact, to which they sometimes reacted by leaning far back or looking away from the monitor. Boyd, et al. explored the use of VR devices which present a visible display of nonverbal social cues in vrSocial [Boyd et al., 2018] and ProCom [Boyd et al., 2017], which included a proximity visualization between users.

Proxemics were used to evaluate the reaction of children with ASD during a free play scenario with a humanoid robot [Feil-Seifer and Mataric, 2010]. The children showed mixed positive and negative reactions to the robot, given that seven children spent a significant amount of time interacting with the robot, and six children spent the majority of time avoiding it.

As discussed, although children with ASD have been observed to maintain a greater distance between themselves and human counterparts, it is not clear how this tendency carries over into computerized settings which contain virtual agents. This study aims to identify idiosyncrasies in personal space between children with ASD and human partners, and look for the same pattern when presented with a virtual character.

5.4.2 Case study: Proxemics and ASD

Human interlocutor configuration

To evaluate differences in perception of personal space between children with ASD and typically developing children, we used the stop-distance paradigm, where the experimental subject stood behind a marked line as an interlocutor approached them by walking head-on at a relaxed pace. In our case, we used an initial distance of 6 meters which is commonly recognized within the largest proxemic zone (the "public" zone). The subject is typically asked to verbalize when the interlocutor is too close, and the resulting distance between interlocutors is measured. During pilot tests, we saw that it would be necessary to adapt the stop distance test to the specifications of the autistic condition. Most notably, we noticed that children with ASD had difficulties verbalizing when they wanted their partner to stop. Therefore, we gave each child a hand-held button to push instead of saying "stop." The children were also told to greet their partner in a friendly way as they approached by performing a hand-waving gesture at the desired stopping point. These measures helped us to record the moment when the interlocutors were asked to stop, without requiring the children to make verbal commands.

Virtual character configuration

In addition to the stop-distance test with human counterparts, children were also asked to perform a similar exercise with a virtual counterpart. For this test, children were asked to stand in front of a large (1 x 2 meter) projection screen. On the screen was projected a three-dimensional virtual environment with a human character standing in the center. The virtual environment was modeled after the laboratory where we conducted testing, so that the view on the screen would resemble the interior of the testing room from the position of the child during the stop distance test (see Figure 5.7). The camera was set at the average height of a 10 year old child. The virtual character was a young male in plain clothes, scaled to average size within the virtual environment, and placed initially 6 virtual meters back from the camera. When the test began, the child remained stationary as the virtual character walked toward the camera. The children were asked to push their button and wave just when the virtual character breached their comfort distance. At that point, the character assumed a standing position and the computer generated a measurement of the distance between the camera viewing point and the virtual character.

Figure 5.7: Virtual character in simulated lab environment

5.4.3 Methods

The experimental protocol consisted of two parts to detect irregularities between preferences towards personal space. The first scenario included a brief baseline interaction where one user would indicate their preferred comfort distance in relation to another child, who they had not met before the experiment. In the second scenario, the user would indicate their preferred comfort distance in relation to a virtual character. We chose these two scenarios as we ultimately wanted to use this information in the development of multiplayer virtual environments, and therefore saw it necessary for the children to show distance preferences in relation to a virtual character and also a potential human playing partner. The two children were then asked to play a 15 minute open-ended play activity together, before completing the stop distance test with their partner a final time.

We tested both settings in an interactive laboratory setting with 32 children

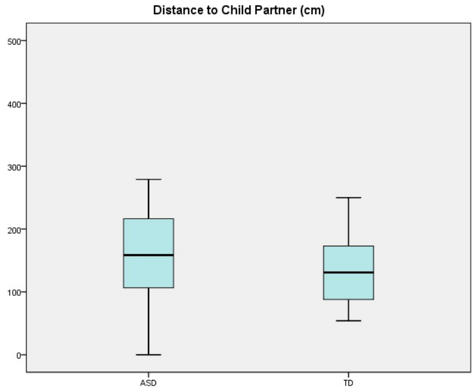


Figure 5.8: Distance preferences with a child partner

between the ages of 10-15 (6 female; 26 male). Each pair consisted of one child with autism (n=16) and a typically developing partner (n=16). The observations and subsequent adaptations are outlined in the following section.

5.4.4 Observations

Although not a significant difference, the children with ASD showed a preference for increased distances between themselves and their human interlocutors (M=156.25 cm, SD=81.11) when compared to the typically developing partners (M=139 cm, SD=60.20) (see Figure 5.8). Children with ASD showed a tendency for a much larger distance between themselves and the virtual character than a human partner, as did the typically developing children. Although the results were largely similar, the group of children with autism showed a slightly lower preference for distance between themselves and the virtual character (M=268.47 cm, SD=125) than did the typically developing children (M=276.87 cm, SD=82.11) (see Figure 5.9). Interestingly, after a 15 minute interaction with their partner, the children with autism showed a much larger decrease in preference for personal space with their partner (M=116.93 cm, SD=64.41) than did the typically developing children (M=142.2 cm, SD=74.44).

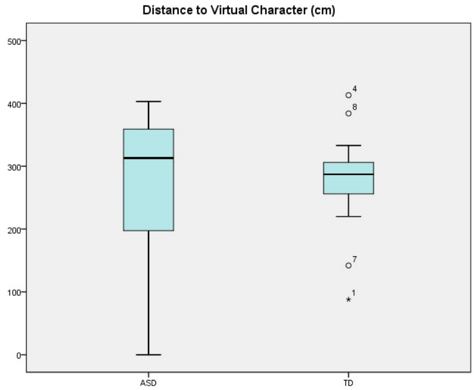


Figure 5.9: Distance preferences with a virtual character

Next, we compared these distances to the average distance between users during sessions with the Lands of Fog virtual environment. Within five trials of the Lands of Fog virtual environment, the children with autism and the typically developing children remained an average of 149.2 cm apart while playing. Thus, the children played the game consistently with the peer-to-peer distance preferences which had been recorded during the stop distance tests. Specifically, children with autism reported that they preferred 156.25 cm personal distance, the typically developed children preferred 139 cm personal distance, and they played the game in between this, at 149.2 cm apart (see Figure 5.10). This shows that the children might have negotiated their personal distance based on their comfort levels with approaching their partner. Also, it gives added evidence that the distances embraced in the virtual environment are relevant as a basis for behavioral analysis.

5.4.5 Implications

As shown in previous literature, children with autism preferred a larger personal space between themselves when presented with a child partner, as

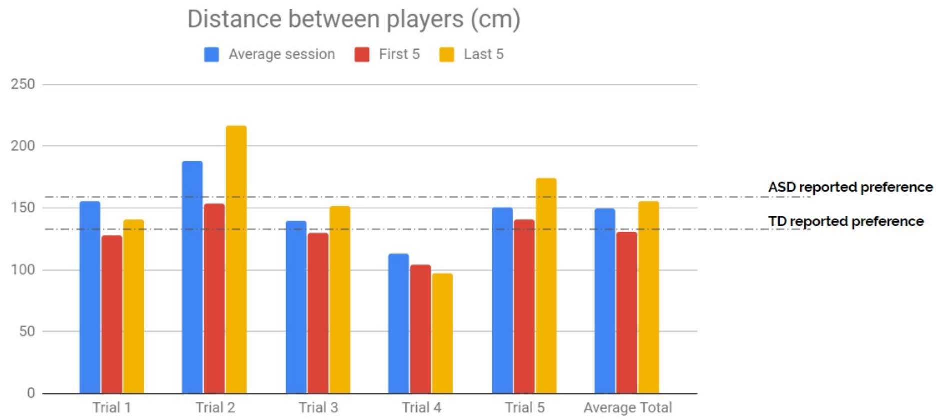


Figure 5.10: Average distance between players during first and last 5 minutes of Lands of Fog sessions, compared to average of reported preferences during the stop-distance test.

indicated by the results of the stop distance testing procedure. This pattern was not carried over into the virtual environment setting, as no significant differences existed between populations of children when presented with a virtual character. This calls into question assumptions with regard to previous observations where children with autism showed irregular behaviors when presented with a virtual character at close proximity. In our case, the children with autism were not comfortable with the virtual character in close proximity, but this pattern was shared by the typically developing children. As both groups of children were not comfortable with the virtual agent when it breached the social space barrier, this indicated that the virtual character might have been perceived as a real being by both children with autism and typically developing children alike. This finding also brings up possibilities for research on why children with ASD might show a stronger aversion to close contact with people, rather than with virtual characters, when compared to typically developing populations.

It is important to note that the perception of the virtual counterpart and the human counterpart were not directly comparable, as conditions related to the virtual environment (viewing angle, believability of the virtual agent) meant the two scenarios differed in key ways. Our goal was rather to search for differences between the two populations with regard to the various conditions presented. In addition, this experiment was done with one virtual character, selected for the similarity in appearance to the predominantly male population of individuals with ASD in this study. Future experiments might test the reaction towards various designs of virtual characters, to analyze the effect of factors which traditionally affect personal space preference (age, sex, personal traits). Future research might strive to reduce these differences and also compare reactions to virtual character in various virtual reality media such as head-mounted displays.

One interesting finding is the fall in distance preference in children with ASD after 15 minutes playing with their partner. In this setting, it seemed as if the children with ASD initially needed more space between themselves and an unfamiliar partner during the initial phases of interaction, which quickly decreased after a few minutes of engagement. Future research could explore this curve more in the development of activities for social interventions for ASD.

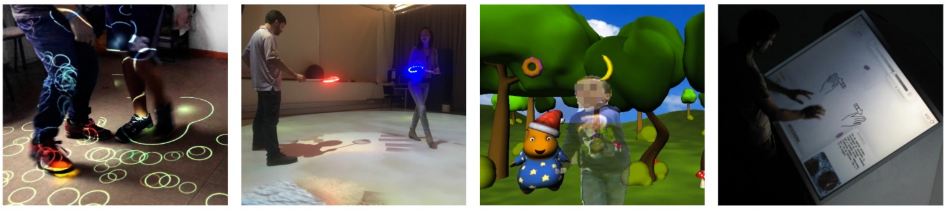
As the children with ASD showed a consistency in need for personal space even when presented with a virtual character, we may assume that proxemics with virtual characters can be taken into consideration when designing virtual environments for social intervention. Ultimately, this work could be further developed to create guidelines which contribute to the development of video game design or avatar-based interaction for autism. Further tests might explore the differences between children with ASD and typically developing children when engaging in free play within virtual environments, and whether social interventions for autism with virtual characters can be more effective when preferences for personal space are implemented.

5.5 The Role of Context in Play

When players enter into an interactive game setting, they undertake a process of discovery and subsequent distinguishing of the rules and goals which will prevail in the play context. However, this process of forming understanding is often altered by the subtle expectations which prevail upon the interaction setting. In this section, we argue that user perception of an interactive system is shaped differently depending on the general context on how and where players first encounter the game. We will use an existing three phase gameplay model, based on invitation, exploration, and immersion, and draw observations from laboratory, museum, hospital, and classroom studies of various interactive playful experiences (see Figure 5.11).

In designing full-body interactive experiences, designers aim to help the user understand that the target play objects or spaces bring intrinsic rules based on their affordances [Norman, 2013], while the user also goes defining those rules subjectively as they engage with the experience. In this process, the user creates their own circle of understanding which will dictate their experience as they play. As the interface, on its physical and software levels, connects players with the game [Saunders and Novak, 2012], most designers focus on designing the play artifact to shape user understanding of the experience [Crowell et al., 2017]. However, the role that context can have in influencing a user's understanding of the system must also be considered by designers of playful experiences, as users do not tend to engage with an interactive system in an isolated manner, but rather in a meaningful social context and in a context of practice [Beyer and Holtzblatt, 1997].

Here we will take a closer look into the understanding formed by users as they become acquainted with an interactive system, and how designers can take into account contextual elements when designing these experiences. Specifically, we will analyze our experiences when creating experimental procedures in laboratory, hospital, exhibition, and classroom settings, aiming to highlight important differences when introducing these experiences to children (see Figure 5.12). These differences might cause problems when



Case 1: GenPlay | Case 2: Lands of Fog | Case 3: Pico's Adventure | Case 4: NanoZoom

Figure 5.11: Four case studies were analyzed for differences in user perception related to experimental context.

designing interactive games for controlled trials and their subsequent transfer to natural settings. We will rely upon a three phase model of play: invitation, exploration, immersion adapted from de Valk, et al. [de Valk et al., 2015], and how a system's context can affect these phases. Our study aims to aid interaction designers to not only consider the design of the interactive system (i.e. interfaces and content) but also the external factors of deployment.

5.5.1 Background

Interaction as a multiple stage model

The idea of interactivity as a multiple stage model, beginning with a system's invitation to engage with the user, was described by Polaine as a concept including four principal parts: invitation to play, the playing field and rules, challenge, and open-endedness [Polaine, 2010]. This model was later abridged by de Valk, et al. to compose the three phase model of open-ended play: invitation, exploration, and immersion. One important aspect from both models is the placement of curiosity as the driver of interest in the initial stage of play, as users may begin by watching others play or observing a hint of interactivity in the play setting. When users begin to experiment with possibilities of the system, they begin the exploration stage, where they determine the various interaction opportunities offered by the play setting.

The play activity can be fueled by internal motivation, where young users use exploration as a means to foment development of understanding and expectations. Alternatively, external motivation is inherent in play settings where young users feel the need to perform the activity correctly, matching expectations of researchers, teachers, or parents.

The Magic Circle

The concept of the "Magic Circle" derives from the phenomenon that occurs when players agree to participate in a play scenario. The term was originally used by Huizinga [Huizinga, 2007] as a functional playground where special rules, generated in real-time through interpersonal processes, prevail, and has since been adopted to describe the real or imaginary "frame" which separates the play space from the "real world" [Salen and Zimmerman, 2003]. As interactive experiences have their own set of rules and possibilities which are separate from ordinary life, these settings have the potential to create an alternate and temporary world where relationships between players and game objects can have increased significance and influence over events that unfold. To create this magic circle, users may either enter into a pre-existing circle of rules as defined by game designers, or create these based on the affordances given by interactions and objects in an open-ended setting.

Just like lighting a flashlight in a cave to flesh out bends in the path, this exploration yields understanding which will serve as their bearings and guide users through decisions taken in the game world. When entering into a predefined scenario without given instructions, users begin exploring and toying around with objects present in order to discover the possibilities which lie in their new environment, later building rules around these.

5.5.2 Case study 1: GenPlay

GenPlay is a full-body interactive system designed for classroom use, consisting of a floor projection of approximately 2.5 x 3 meters in area. The system is meant to be a collaborative activity which fosters socialization between children as they explore the interaction possibilities of the open-ended design featuring generative audiovisual effects.

Project	Design purpose	Context
GenPlay	Foster collaboration between classmates through open-ended play	Classroom
Lands of Fog	Scaffold social initiation between children with ASD and partners	Laboratory, Classroom, Museum
Pico's Adventure	Elicit social behaviors in children with ASD collaboratively	Hospital, Museum
NanoZoom	Explore the nanoscale world	Laboratory, Museum

Figure 5.12: Design purposes and corresponding experimental contexts of the case studies.

GenPlay was tested at a mainstream elementary school in Netherlands with 57 children between the ages of 9-11. The system was installed for two days in a spare classroom in the school that children visited for music classes. On the first day of the study, children played in the virtual environment for 4 minutes with a partner of the same classroom chosen by their teacher. On the second day, the entire class came together, and children took turns playing in the system with a different partner from the day before with their classmates and teacher present.

5.5.3 Case study 2: Lands of Fog

Lands of Fog [Crowell et al., 2017] is a collaborative virtual environment designed for children with autism to practice socialization and collaboration while playing with a typically developing partner.

The system was tested in three different settings, each with minimal directions before playing in order to encourage exploration of game possibilities. First, we conducted a series of laboratory trials with 14 children with autism between the ages of 10-14 who played with a typically developing partner. Each session lasted for 15 minutes, and was conducted in a university laboratory. Parents, two researchers and a psychologist were present during the experiments. Second, the system was tested in an elementary school setting in London with a special needs program. The system was installed in the gymnasium of the school, and over the course of one week, 20 children with autism came to play with a typically developing partner from the same school. The children played for 15 minute sessions, which were supervised by a member of the special educational needs staff and two researchers.

Finally, the system was installed in a science museum for 4 days, during which 1700 student and families came to visit. Children could enter and leave the system as they wanted. In this setting, a researcher was available to facilitate the game. Two participants played at a time, and some smaller children were accompanied by a an older sibling or family member.

5.5.4 Case study 3: Pico's Adventure

Pico's Adventure was a Microsoft Kinect-based video game created to elicit social behaviors in children with autism collaborating with a peer or a family member [Malinverni et al., 2016a]. The children operated the system with their bodily movements as they stood in front of a large TV screen.

Pico's Adventure was tested with 20 children aged 5-7 who participated in four experimental sessions of up to 15 minutes each. The system was installed in a hospital room used for autism therapy. As an introduction to the system, children were explained the goals and game narratives. Parents, a therapist and a researcher were present during the sessions, and parents actively participated as collaborators in two of the four sessions. Later the system was installed in an art museum for a weekend during a technology fair geared towards people with special needs. During this session, 11 users with various disabilities played with the system. Visitors could approach the scenario at their will and play for the duration of time that they wished. A researcher was present and users were accompanied by family members.

5.5.5 Case study 4: NanoZoom

NanoZoom was an interactive installation created for general audiences, to help users conceptualize the size of objects in the nanoscale in a playful and collaborative way [Mora-Guiard and Pares, 2014]. The system was based on a large multi-touch surface where users could place and resize virtual representations of various familiar objects. As players engaged in exploring the game, they could enter a smaller scale by zooming into the virtual environment, making the objects 10x larger. Selected objects would then overflow from the sides of the interactive table onto a large floor projection of 10 x 4.5 meters. This also served as an invitation for participation and discussion from nearby museum visitors.

NanoZoom was tested in two different environments. First a series of experimental trials was conducted with 64 children, aged between 11-13 years old, in a sectioned-off area of a science museum. Children played for a maximum of 10 minutes. Children were briefed on how to use and interact with the application, and were asked to explore all possible scales. The system was then installed on the exhibition floor of the museum, which was open to the public over the course of 4 months. During this time, users could come and go as they wanted, ranging from players who would individually navigate through the whole experience by themselves, to more than 12 children playing at the same time.

5.5.6 Methods

In this study we address four full-body interactive playful experiences which were tested in either experimental, school, hospital and exhibition contexts. We also discuss observations made regarding contextual effects on user exploration and understanding of the system during the three stages of play. The discussion that follows includes analysis of patterns which were consistently observed in various settings.

For the following discussion, each of the aforementioned experiences was evaluated in terms of the configuration of the settings in which they were deployed. These results were then grouped in terms of setting and user behavior during each stage of play. Below we will discuss how these impacted the user's experience during the three stages of play (invitation, exploration, immersion), pulling out relevant observations related to contextual factors.

5.5.7 Observations

Laboratory trials

During the invitation phase of Lands of Fog, as children entered the play arena, their movements were generally slow and cautious. They spent the first few minutes walking through the scenario, observing parts of the virtual environment. At this point, a few children became disengaged if a long time passed without any significant game actions. As they learned about the game in the exploration phase, most children increased their actions and conversation towards the latter half of the 15 minute session. Some users expressed confusion about the purpose of the game. However, this expression was not made in the exhibition sessions, when players had the opportunity to come and go from the scenario as they wished. It must also be noted that the laboratory setting was created to test the game among a population of children with autism and typically developing peers. The science museum exhibition catered to a general audience.

During the exploration phase of Nanozoom, children tended to stand in front of the large multi-touch screen and quickly cast a new object from the selection menu. During the initial scales children would explore the objects by moving them around the interactive surface, but as children advanced to the immersion phase, their behavior was less exploratory and focused towards reaching the final scale.

Museum setting

In the invitation phase of Pico's Adventure, many participants would approach the system cautiously and stand a short distance away, glancing furtively towards the system. When they began to explore the system, the participants often showed pleasure at the simple act of seeing themselves on the screen and having an impact on the virtual environment. During the exploration phase, users would often call a family member or friend over to join in playing the game with them. Only one user used the system in single player mode. Many users did not immediately understand the concept of the collaborative actions, but after a brief mediation from the researcher, they pursued the collaborative goals.

For NanoZoom, museum visitors would approach the table in a cautious manner. Many users first observed the information panels around the installation. During the invitation phase, if another person was already interacting with the system, people would normally observe from outside the floor projected surface. When objects overflowed from the table, bystanders were engaged and moved close to the multi-touch surface, typically turning to face the same direction as the main user was facing. Many users would then interact with the objects of the table, while a main user would still have the role of orchestrating the shared experience.

From both experiences, we saw that in the exhibition settings, the users' awareness of the context of the system appeared to be more shaded by their own intrigue, and their understanding of what to do was guided by the possibilities that they perceived based on the affordances of the system. This process of gradual discovery allowed users to create their own rules as they explored and interacted with the system. During this process, we could say that the rules and understanding of what was happening in the installation was formed on their subjective perceptions of their explorations and the intrinsic motivation to understand how the system worked. This poses a difference when compared to the experimental setting, where users are brought to the setting of the interactive experience and guided to play for a certain period of time, which could have influenced their understanding of expectations of the experience. The most observable difference between the laboratory and exhibition setups was the curiosity which players showed outside of the formality of controlled trials, during the invitation and exploration phases of play. This is consistent with the indicators of internal motivation, i.e., trying to understand how the game works and what is its purpose.

Hospital setting

In the hospital trials of Pico's Adventure, children with ASD were told to explore possible interactions with their body to achieve their goals. However, during the invitation phase, children would tend to stop moving and turn to the therapist to ask for help on how to achieve their goal. Once children discovered or were explained how to interact with the system, they would quickly explore the possibilities within the game trying to achieve the goals set forth by the system. Children tended to ask the therapist for help when they did not achieve their short-term goals.

One way this setting differs from other contexts is that when players were explicitly explained the rules of play, the interactions at their disposition and what was their goal, they would tend to rely more on the psychologist and the researchers when problems occurred. Although the presence of authoritative figures is also a resource for the understanding of the experience by the users, it might be also a distraction when interaction designers try to understand how users approach their design and setting, and how it will be used in more ecological settings.

Classroom setting

In the elementary school setting of Lands of Fog, we observed a higher level of formality among students while playing than in the laboratory and exhibition environments. This might be due to the fact that their teachers were present instead of their parents. At the beginning of the week, the students were somewhat slow to catch on to the gameplay mechanics, compared to the laboratory trials. This picked up towards the end of the sessions, and as the time spent learning to play lessened, we also saw a shallower depth of actions that the children engaged in while playing. Many spent the entire game engaging in the same initial mechanics that they learned during the primary stages of gameplay, even though there was additional content to explore. Additionally, a sort of language was developed between participants, as we saw that words like "leveling up" to describe changes in avatar texture were increasingly common towards the end of the sessions. We attributed this to the possibility the players might have shared information between sessions with other classmates, which led to a common understanding regarding gameplay goals.

In the classroom setting for GenPlay, originally students played the system alone with a partner, externalizing their impressions as they discovered how the system functioned. On the second day, when a teacher was present and classmates took turns playing in the system, we observed less communication between children who were actively playing in the system, as the majority of communication was between players and the children spectators. In this way, the child spectators stayed in the invitation phase for an extended time, as they could preview the system while their classmates were playing. In this case, the spectators played an important role in lending support to the children playing, pointing out observations and actions for the players to try. When it was their turn to play, children could try interactions discovered by the other students, and discovery of the system went much faster than during the isolated play setting. Teachers were asked to encourage children to participate, and when one teacher became involved in supporting the children who were playing, we observed an increase in engagement from the surrounding children as well. Conversely, as a teacher became involved in another task while children were playing, the students also dedicated more attention to side activities than actively engaging with the students playing.

5.5.8 Implications

Across the settings presented, users relied on different methods to form their understanding of the systems during the initial phases of play. In experimental settings where previous knowledge or human mediation was available, exploration of interaction features was limited, as users deferred to goal-directed behaviors and searched for an overarching purpose. In the exhibition and classroom settings, the understanding that the children gave to the system was based on their experience and on the intersubjective process that happened with other users of the experience. Depending on the characteristics of the setting or how the experience is introduced to users, the context can greatly affect immersion and exploration of game phases, and the formation of user motivation. Further analysis on this topic can aim to understand how this motivation can work towards greater player engagement with respect to project aims, such as education or socialization in a multiuser setting.

Chapter 6

Contributions in Evaluation Methods for Full-Body Interaction

6.1 Introduction to this chapter

In this chapter, we will present four methods for data collection which we have utilized in the multimodal data analysis of the projects discussed in the previous chapters. We will begin by introducing video coding of recorded experimental sessions as a means to identify occurrences of social behaviors. Along with this, we will introduce a novel methodology for structured observation of social behaviors in virtual environments for autism, and the corresponding validation over the course of 20 intercoder reliability studies. Next, we will discuss the potential and limitations of self-evaluation as a means of data collection with children with autism. Topics will include tablet-based questionnaires, standardized questionnaires, and non-standardized questionnaires. We will discuss the current state of physiological signal implementation in ambulatory environments for autism and how we used this in our systems. We will finally discuss how we elicited information about children's behavior from system logs files in our interactive systems.

6.2 Video coding

Adapted from the article: *A Structured Video Coding Method to Achieve Reliable Time-Stamped Coding of Social Behavior for Integration in Multi-modal Evaluation: A Case in Virtual Reality for Autism*

Methods to evaluate social skills training for autism currently rely upon behavioral coding methods developed for traditional intervention settings based on the psychological profile of autism, which do not take into account the range of behaviors implied in ambulatory virtual reality settings. Here we will describe a methodology for coding social skills interventions for autism which use embodied interaction, taking into account non-verbal communication and response to active systems. In addition, we discuss how data from video coding may be correlated with system data (log files of system decisions and actions) and/or other types of data achieved in real-time. In particular, we have developed this method in the context of a mixed reality experience that fosters social initiation behaviors on children with and without autism playing together. Our method proposes on the one hand, a coding grid that has been evolved through a number of projects and iterations to successfully code social initiation behaviors. On the other hand, our method proposes a structured step-by-step scheme to video coding that provides a time-stamped set of behavior data that can then be correlated with other real-time data sources. Results are presented regarding both the tool's propensity towards the range of behaviors presented and inter rater agreement scores over the course of 20 coding exercises.

6.2.1 Background

Video coding of social behaviors remains one of the most common ways to evaluate the efficacy of social interventions for autism. Typical video coding methods include recording of intervention sessions to be used in posterior coding of externally observed or overt behaviors. Coding may be done using qualitative analysis through a bottom-up methodology, referring to the observation and denotation of target behaviors, which are later categorized based on affinities. The most common way to do coding, however, is by quantitative analysis using a top-down methodology, where unbiased coders watch recordings of sessions and mark target behaviors using a predefined coding scheme. Typically, the number of observed behaviors are counted for the duration of the coded session and used to evaluate the session. However, when coding behaviours of participants during interventions that use an interactive system, much richer results may be obtained if the data from video coding is correlated with system data (log files of system decisions and actions) and/or other types of data obtained in real-time, such as physiological data. This implies that the data from video coding cannot be aggregated for the totality of the intervention session. Rather, every observed behaviour must be time-stamped to be able to correlate its occurrence with the occurrence of events from other sources (e.g. a decision of the system to activate a certain action, or a change in heart rate from the participant). This does not only increase the difficulty of the video coding process, forcing the coder to be much more precise, but also increases the difficulty of achieving high inter-rater agreement values. The reason being that coders do not only have to agree on the amount of each type of behaviour that has appeared during the session, but they must also agree on the instant in which each behaviour instance has appeared. In our case, we aimed to create such a flexible video coding scheme to record social behaviors in a full-body interactive system which encouraged children with autism to socialize and collaborate during face-to-face play with a child peer.

We followed a comparative study experimental procedure, testing our full-body virtual environment Lands of Fog as the experimental condition (what we call *active intervention*). We used a LEGO intervention exercise as the control condition to follow habitual intervention methods that use construction tools and toys (which we call *passive intervention*). For more information on the experimental procedure, see Chapter 4. Bauminger's social intervention coding scale [Bauminger, 2002] forms the basis for the coding scale we used, which is adjusted for interventions for children with autism from a psychological stance and was implemented in social skills therapy in another research project by our collaborator organization Hospital Sant Joan de Déu. Therefore, we adapted Bauminger's method to apply to both passive and active intervention practices, through direction of the social behaviors (to whom they were directed). The coding scheme also allowed us to differentiate between social interactions which were directed towards the play partner, or towards the system or other people who were present in the experimental setup. This distillation was important in understanding the efficacy of the interactive system on encouraging social behaviors between a child with autism and a peer while playing face-to-face.

Previous Work

Social interaction involves consistent communication between two or more individuals in the form of initiations and responses. Research involving children with high functioning autism found that these children are capable of sustaining social interaction once it has been started, but have lower rates of initiating play and social sequences themselves. This has shifted the focus of interventions towards fostering social initiation behaviors in children with autism.

This forms the basis of a 2002 study by Nirit Bauminger on encouraging social understanding and interaction in high functioning children with autism. A scale was developed to observe social behaviors, in which social initiations and responses are marked into three categories: positive social interaction, negative social interaction, and low level interaction. The scale was used to code behaviors during playground recess sessions before and after the intervention. In Bauminger's study, this coding scale is used in parallel with other assessment tools such as problem solving measures, an emotional inventory, and teacher reports to detect changes in emotional understanding and social skills.

The scheme presented in Bauminger's study is based on Hauck et al.'s Behavior Coding Scheme for children, which was used to evaluate the occurrence of social initiations in retarded and autistic children in naturalistic settings [Hauck et al., 1995]. In this study, Hauck concludes that structured play environments provide a positive context for scaffolding socialization in autism. Bauminger proposes changes to fit the playground context such as sharing experiences/objects and social communication. Another important addition in Bauminger's case was the addition of social responses as a category alongside social initiations. Although the definition of social items found in Bauminger's adaptation is well-adjusted to interventions for children with autism from a psychological stance, it does not account for settings where an interactive system plays an active role in encouraging socialization towards or between the children.

In the field of developmental psychology, research has previously focused on defining categories for play as an individual progresses in social development and understanding of others. In 1932, Parten divided social participation into six categories: unoccupied behavior, solitary play, onlooker behavior, parallel play, associative play, and cooperative play [Parten, 1932]. Later, Piaget defined criteria for play and classified play behaviors into stages of cognitive development [Piaget, 1951]. Based on a developmental psychology approach, observation schemes have been created for use in social and collaborative play settings for typically developing children.

The Play Observation Scale (POS), devised with the underpinnings of developmental psychology, first divides behaviors into Play or Non-Play, then assigns qualifiers such as social or cognitive play. Within these categories are items such as functional play and exploration. The Outdoor Play Observation Scheme (OPOS) is an evaluation scheme developed for head-up games for children, or those with play patterns similar to outdoor games [Bakker et al., 2008]. In this evaluation scheme, researchers distinguish between point events and states, depending on the continuity and duration of the behavior. In this way, both event sampling and time sampling techniques are combined. The scheme also categorized the direction where the children looked as the focus of the behaviors. Using this scheme, observers watch videos of the play activity and make structured observations of the children's physical activity, focus, social interaction, and general issues. The scheme makes a useful step in including focus of the children's activity; however, the social interaction parameters do not include items which are specifically catered towards the abilities of children with autism from a psychological standpoint.

In the field of full-body interaction, Bianchi-Berthouze classified verbal and non-verbal behaviors presented during social game play [Bianchi-Berthouze, 2013] into categories based on the Autism Diagnostic Observation Schedule [Lord et al., 2001]. This taxonomy included additional verbal identifiers such as speech, and non-verbal identifiers such as empathic gestures. Although the project was not designed specifically for children with autism and does not include qualifiers such as "initiation" or "response", the differentiation between verbal and non-verbal behaviors adds an additional level of structure compared to the other tools, taking into account the importance of non-verbal behaviors in social interventions for autism.

Since no existing observation scheme was found that was suitable and accounted for settings where the system plays a role in encouraging socialization towards or between the children, an adapted observation scheme was developed during an iterative development process.

6.2.2 Development of coding scheme

We worked with the Boris video coding software, which allows for multiple videos to play simultaneously. As we had two cameras and microphones positioned at opposite ends of the play arena, this program allowed us to view the experimental session from both sides at once. After the sessions, a native Catalan and Spanish speaker transcribed the speech from each video onto an excel file, so the coders would have a clear reference to use when evaluating social behaviors.

Bauminger's coding scheme proposed five categories of interactions: social initiation, social response, positive social interaction, negative social interaction, and low-level interaction. Each category has several items which can be tagged for each behavior. When we reviewed these categories in the context of our system, we agreed that some items could be combined, such as looking away and avoidance. We developed a hierarchy of interactions and arranged their application order in a flowchart to aid the coders to have a clear step-by-step set of criteria to code. In our coding scheme (within Boris, see Figure 6.2), in parallel with the flow chart, one item can be selected from each of the first three categories (verbal/non-verbal, direction, and type of interaction), and the coder can select items within only one of the last four categories (positive social interaction, negative social interaction, low level interaction, or anxiety indicators). This flowchart may be found in Figure 6.1.

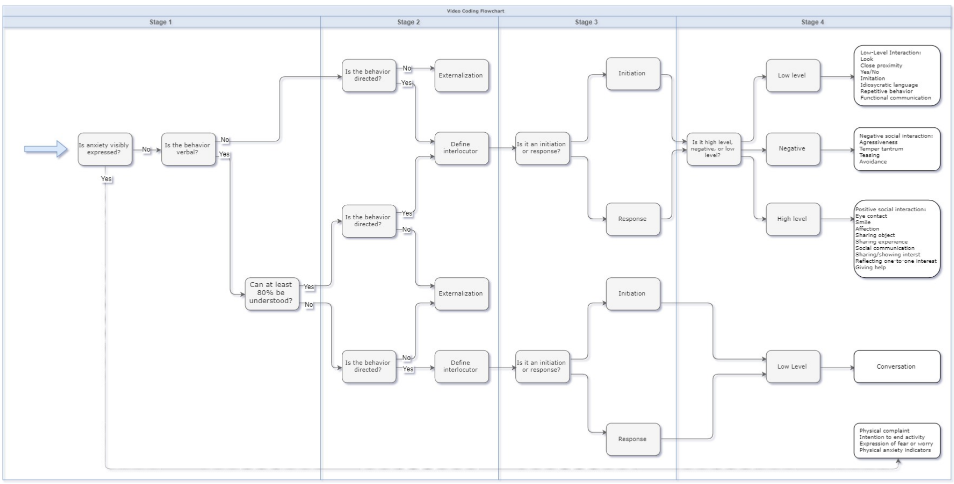


Figure 6.1: The study resulted in a video coding flow chart.

When we began working on a coding scheme, we first identified whether a behavior was an initiation or a response. However, because certain interactions were uninterpretable due to lack of audio definition, we could not determine if the behavior was clearly directed to the other child, or directed towards the game. Therefore, in our flow chart, after deciding that the behavior is not an anxiety related behavior, we decide whether the behavior is verbal or non verbal. From there, if it is verbal, we note if we can understand at least 80 per cent of what is being said. This was an important feature, because it allowed us to know if comments were appropriate and on subject, or repetitive speech. If we heard that the child was completing an initiation or request within a social sequence, but could not understand 80 per cent of the words, we marked it as conversation.' If the behavior was understandable, and directed towards their play partner, we then would have enough information to mark it as an initiation or response, and also to mark if it was a high or low level response.

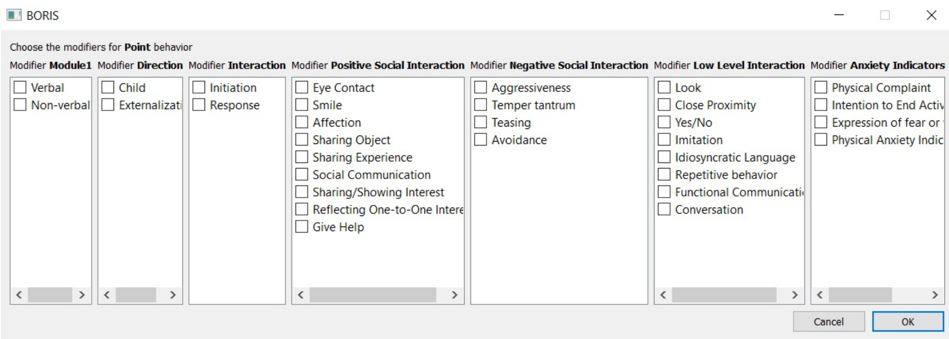


Figure 6.2: Coding categories organized in Boris software format

At the core of the scheme, each social behavior is determined to be an initiation or a response. From that point, the behaviors have other criteria added, like verbal/non-verbal. If the behavior is not explicitly directed to someone or directed to a character other than the child play partner, it is considered an externalization. This was important in our case, as the game elicited many comments that did not lead to social interaction between the children specifically, but rather between the child and the game or the child and their parents. We considered these externalizations as valuable to code due to their potential of being picked up and generating a response by the other child and hence becoming a social interaction.

We found that some actions started as a low level interaction and turned into a high level one. For example, sometimes a child would look at his partner, then come into close proximity, and then share an experience. In that case, if they were part of the same social sequence, we only took into account the highest level interaction which we considered to be the most meaningful. This sometimes meant watching the sequence until the end and then evaluating which part of it was the highest level interaction. It is also valuable to mention that each initiation or response needed additional criteria as a positive or negative, low level behavior. Externalizations did not have these additional criteria.

All of the coded behaviors were then exported to a spreadsheet list as a default of the coding software. However, this was not useful in our case to get an overall vision of the session. Therefore, interactions were converted into a visual form using a directional chart. At one end of the chart is the child who started or maintained the interaction, and the qualifier for initiation or response goes in the middle of the arrow (see Figure 6.3). This was particularly useful when discussing among researchers about particular social events, as charts could be aligned to see inconsistencies.

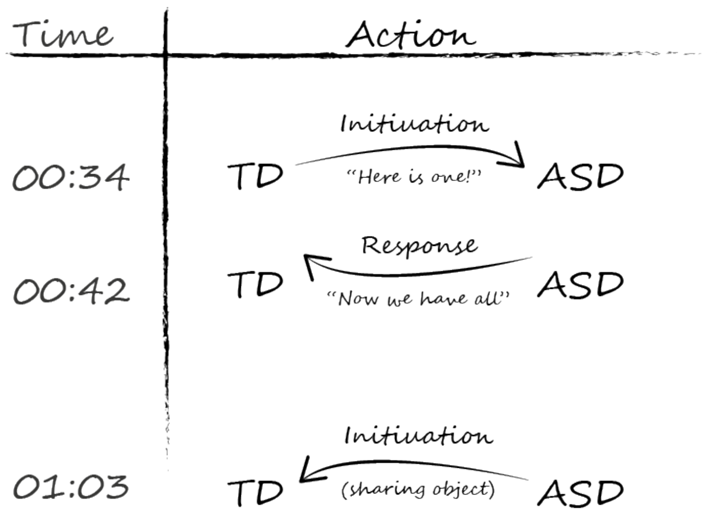


Figure 6.3: Visual representation to understand direction of behaviors

In the case of Bauminger's experiments, the sessions were coded in vivo, where a coder watched the children for 50 seconds and recorded behaviors for 10 seconds. Therefore, the observations were aggregated during a large window of observation. As we were gathering system data (log file) and physiological data alongside the behavior coding, we needed a high degree of time precision in coding. It was therefore natural to use a time-based coding method, where precise timing of the events is essential. Also, because of this we did not choose to code in vivo, but rather video recorded the sessions from two opposing points of view, as described above, and then coded those recordings with the possibility of watching back and forth, so as to not lose details and to be able to define the exact second at which the observed event occurred.

In adapting Bauminger's coding scheme, we also discussed how to differentiate between quick, single instance events and those events which lasted for an extended period of time. We decided to use "state" and "point" event qualifiers, and we determined that a point event was a single action which did not extend for more than five seconds. A state event lasted for more than five seconds, and ended with a change of theme or action, change of interlocutor, or a response that included a new social initiation from the other child.

The choice of a five second window to differentiate events was made according to the criteria defined by Hauck. In the case that multiple interactions occurred within five seconds, we decided to record the event with the highest level of interaction to be able to capture those events which are most significant for autism. The exception to this was when a response included an initiation, as they are both the highest level of interaction. In those cases we recorded both events despite occurring less than five seconds apart.

Although two children were playing together in the experimental setting, only the behavior of the child with ASD was coded. We have nonetheless the possibility of coding the behaviors of the non-ASD children in the future and correlating it with the system's log files, as well as with their physiologic data. As our experiment gathered information about the children's active state via physiological sensing, we also added a category of anxiety indicators to the coding scheme in order to relate specific anxiety indicators with physiological arousal. These anxiety indicators were derived from the Liebowitz Social Anxiety Scale [Liebowitz, 1987] and included behaviors such as physical complaint or intention to end activity.

The coding scheme has been developed in 20 iterations by randomly choosing video segments of the first and last five minutes of both the experimental and control conditions. In order to evaluate the progress of the design decisions we made during 20 iterations, we calculated the inter-coder reliability between three coders via Cohen's Kappa using the main social interaction components of the observation scheme such as social initiation, response and externalization. We used two methods for comparing the results of these coders which were similar to the methods used in commonly used video coding software tool 'Noldus Observer XT' [Zimmerman et al., 2009]. The first method was 'Frequency-based' method which was based on comparing the total frequency of events or states.

The second method was Frequency/Sequence based' method, where the sequence of events was important and each individual event or state coded was compared across coders. As we needed a high degree of time precision in the coded data, the results from the second method were crucial in this experiment. Although the Kappa scores of Frequency/Sequence based method were lower than the results of frequency-based method, we realized that there was an increasing trend in the Kappa scores of Frequency/Sequence Based method in each iteration of the coding scheme. For example, in the last iteration of the development of our video coding scheme, we reached the highest percentage of agreement scores between coders, which ranged from 0.68-0.8. With this level of agreement, we kept the coding scheme as the final version of the coding criteria.

6.2.3 Validation of coding scheme

Thirty-six children participated in the trials (18 pairs), of which 18 children had a diagnosis for autism and 18 were considered typically developing play partners. For each trial, one child with autism played with one typically developing peer. The experimental design may be found in Chapter 4.

The evaluation of the coding scheme consists of two parts. First we will explore its usability and inter-coder reliability using a selection of the data following the finalization of the coding scheme development. Then we will assess the applicability of the scheme by comparing the data from all coded videos.

Inter-Coder Reliability In order to evaluate the main social interaction components of the observation scheme, including occurrences of social initiation, response and externalization, the inter-coder reliability has been calculated for these classes, both through percent agreement and Kappa (Cohen's Kappa) in a randomly selected new video. We used the frequency/sequence based method and the Kappa Scores ranged from 0.60 0.69 and the percentage level of agreements ranged from 0.71 - 0.78 between 3 coders.

Comparing Play Behaviors Evoked The results below include a descriptive analysis of tendencies identified while coding the VR and LEGO conditions. The data is meant to show flexibility of the coding scheme through breadth and occurrences of behaviors observed while coding conditions with different types of media, i.e. a technological intervention and a non-technological intervention.

The most common high level behavior in the VR condition was "Sharing Experience", followed by "Sharing/Showing Interest." In the LEGO condition, the most common high-level behaviors were "Sharing Experience" and "Sharing/Showing Interest." The most common low level behavior in the VR condition was "Close Proximity", and the most common low level behaviors in the LEGO condition were "Conversation" and "Look."

In the VR condition, 71.0 per cent of behaviors were clearly directed at the play partner, while 29.0 per cent of behaviors were considered "externalizations," or not directed at the play partner or game. A similar trend existed in the LEGO condition, 72.8 per cent of behaviors were directed to the child partner, while 27.2 per cent were considered "externalizations." Although we made the tool flexible to verbal and non-verbal options in both high-level and low-level behaviors, we also noticed that 80.3 per cent of initiations were verbal and only 19.7 per cent were non-verbal in the VR condition. For responses, 67.8 per cent of responses were verbal and 32.2 per cent were non-verbal. A similar trend was recorded in the LEGO condition. Finally, we noticed that initiations were more likely to be high level behaviors than low level behaviors, with 64.3 per cent of initiations classified as high level and 35.7 per cent considered low level in the VR condition. With responses, high level and low level events were evenly split at 50 per cent each. A similar trend existed in the LEGO condition.

6.2.4 Utility

We have presented the development and assessment of a methodology for coding social initiations for autism in technology-based social intervention systems, designed to allow for precision in time-based data when using multiple data sets.

The coding methodology was improved through an iterative process, responding to issues which arose when trying to reach the interrater agreement. This process helped to identify points of uncertainty in the existing coding methodology and adapt it to reach a version which suited our context. An extended development period was necessary to reach acceptable percent agreement scores until we were confident that coders were well trained and little guessing was likely to exist with the current version of the coding methodology.

With regard to the assessment of the methodology, when our final coding methodology was applied to a randomly selected new video our scores were found acceptable according to current standards set by the WWC; where levels of agreement at or above 0.60 for Kappa and 0.80 for percentage agreement are considered acceptable.

Moreover, as the percentage of events which were directed to the peer or not directed to anyone (externalizations) are similar in both conditions, we can understand that the coding methodology effectively levels out differences which might be caused by interactions directed at the game characters.

As we aimed to compare data across media platforms, the distillation of direction of behavior helped us to discard behaviors directed toward the game. This allowed us to compare data from the active VR system with the passive LEGO setting. The division of social behaviors into these directions was done to create a common understanding between coders, as a point of discussion centered around the inclusion of behavioral events directly related to the game characters. As the purpose of the game and characters was to foster social initiation between the child with autism and the peer player, a consensus was reached that interactions directed towards the game in any capacity should not be coded as social interactions for the purpose of this project. However, a further iteration of the coding scheme might further introduce separate categories for social behaviors towards game characters, researchers, and other individuals present.

The presence of several non-verbal behaviors in the low-level section naturally created a correlation between non-verbal behaviors and low-level interactions. For example, "Look" is by nature non-verbal, so it would not be coded as verbal unless it was combined with another verbal behavior such as "Yes/No." A bias seemed to exist in the coding of high and low level behaviors, as most initiations were considered high level events, although the coding scheme allowed initiations to be high, low, or negative level events. This trend might be explained when looking at the categories for high level behaviors, as categories such as Sharing Object and Sharing Experience might occur more as conversation beginners than responses. Similarly, the low level categories "Yes/No" and "Imitation" also lend themselves more towards responses to another's behavior than initiations.

In response to this, the majority of initiations were verbal, as they had a tendency to be high-level events. However, we did see several occurrences of initiations as non-verbal behaviors such as "Close Proximity" when a player approached their peer with social intent, without being solicited. This project focused on High-Functioning children with autism, who at minimum possess a basic level of verbal abilities. In the case of this population, an emphasis is put on verbal events. For projects involving low functioning children with autism, non-verbal events might take on more importance.

6.3 Self-evaluation

Although the communication difficulties characteristic to the autistic condition pose a risk in gathering reliable data via self-evaluation, we saw it necessary to include the voices of children with autism in gathering data for our projects, as no one can understand their needs better than the children themselves. Thus, we included data from interviews or questionnaires in all of the projects mentioned in this thesis. This ranged from informal post-experiment interviews with children and parents, to tablet-based standardized questionnaires. Because many studies note problems with gathering reliable feedback from children, we searched for methods to elicit information which adapted to their strengths and capabilities. This section will outline our rationale and process of defining self-evaluation methods.

Reliability of self-evaluation in children with ASD Previous research in design has highlighted the challenges in gathering feedback from children with regard to their preferences in interactive systems. One tool created for children is the Fun Toolkit. This tool includes the Again-Again Table to measure engagement, the Funometer and the Smileometer to measure comparative fun, and the Fun Sorter, which can be used to respond to questions such as "Which activity was easiest to do?" [Read et al., 2002]

Problems reported have included children's tendency to produce biased results using tools such as the "Smileyometer", resulting in consistently choosing the more positive ratings on the scale and that younger children give higher answers [van der Sluis et al., 2012]. Along with challenges in eliciting feedback from children comes extra challenges related to communication difficulties in children with autism, as studies have shown that children with autism have difficulties with proprioception [Blanche et al., 2012], or the sense of one's own movement and position. Few research studies have searched for reliable self-report methods involving children with autism. However, in a study done by Kirby et al., researchers highlighted the importance of using contextual information and sensory details in framing interview questions [Kirby et al., 2014].

Non standardized questionnaires

One of our initial hypotheses with the Lands of Fog system was that children would show motivation to engage in playful experiences in the virtual environment. As we did not have access to information on the children's behavior outside of the experimental sessions, we used pre- and post- session questionnaires administered to the parents or teachers to gather information related to the children's motivation during the play sessions. Example questions asked in Likert-scale form included "How flexible was your child compared to normal?" (a full copy of the pre- and post-session questionnaires can be found in the Appendix, A.1-A3).

During the second set of trials, we removed the parental feedback and interviewed children directly, reading each question aloud to the children and allowing them to chose an answer individually (a full copy of these questions can be found in the Appendix, A.4). This was done for several reasons. First, parents would normally fill out the surveys aloud together with their children after the completion of the session, asking their children for their feedback before selecting a number which they felt fit their idea of how the session went. We felt like this neither allowed room for the children's unfiltered feedback, nor the parent's true impression of the system, as many were also hesitant to give critical opinions on a system which was built with a social cause. We felt like the positive opinions might have been given more in agreement with the well-meaning intention of the system, and not with the experience of the child. Second, as the experimental plan required multiple sessions, this also meant that the same parent had to be present at all sessions to remove the risk of subjective differences in reports from one parent to the next. Finally, acquiring a post-session recording after the final session was difficult, as only two of the 10 families contacted filled out the final questionnaire sent by email.

Standardized questionnaires

With some research into social therapies using ICT for children with autism, we discovered that questionnaires and interviews remain common means for gathering feedback for interactive systems. However, we also realized the trend that many projects were using non standardized measurements to gather data. These studies were useful in isolation, but could not be compared to other systems from data alone. This prompted us to search for standardized tools to measure the efficacy of our system in eliciting social behaviors.

For the second set of Lands of Fog trials, we kept the initial pre-session questionnaire, but also added the Child-Behavior Checklist as a means to understand each child's disposition and character nuances [Achenbach et al., 2012]. The CBCL is recognized in both research and clinical settings to screen for tendencies such as aggressive behavior and social problems. We included this in our questionnaire methods to get information on each child's behavior outside of the sessions which could match to patterns we saw within the sessions. It was also used to screen participants for additional conditions such as hyperactivity. The surveys were filled out by parents before coming to the sessions and were scored by the project psychologist.

As a goal of our experiments was to determine differences in the children's active state while playing in our system, we saw it necessary to gather information about the children's state while outside of the experimental setting too. For this, we used the State-Trait Anxiety Inventory for Children (STAIC) [Spielberger, 2010]. The inventory consists of two parts: one that measures the overall tendency of the child towards anxious behavior in daily life, and a second part which measures anxiety on a short term scale, specific to certain situations. Each part consists of 20 questions. The first part was administered to parents at home and was filled out before the first trial. The second part was administered to the children before and after each activity. This was meant to gauge changes in each child's anxiety level in relation to the interactive system and control activity. As children filled out the questionnaire which reported their perceived anxiety level, we continued to gather physiological data, to later determine the accuracy of each child's self-reported active state.

Tablet-based questionnaires

As previous research had detailed the success of using sensory elements in interviewing children with autism, we decided to make a tactile interface for them to respond to interview questions [Kirby et al., 2014].

This was also seen as a way to minimize the uncertainty of open-ended questions, which could be compromised by limited communication abilities. We experimented with various types of interfaces, such as tangible sliding bars on Likert scale questions, Smiley face cards, and computer based systems, and found that children had an immediate and natural understanding of sliding scales based on tablet interfaces. It is worth nothing that the tablet interfaces were much easier for the children to use than the mouse and keyboard interfaces, due to the sliding nature of the Likert scale questions, which they found hard to click on and drag with a mouse along the predetermined line. The tablet interface adapted well to the motor issues encountered by some children with autism, and it seemed like it made the repetitive task of answering questions slightly less monotonous.

We used the Affective Slider scales, which we judged related well to our questions on the children's active state [Betella and Verschure, 2016]. The Affective Slider consists of continuous Likert scales with icon images to measure agreement, arousal, or pleasure (see Figure 6.4). Together with these sliders, we asked questions such as "How well do you know your partner right now?" We also configured the STAIC to the tablet format, and children answered inventory items such as "Right now, I feel calm" with one of three responses: Not at all, Somewhat, A lot. All questions were translated into Spanish and Catalan, as we acquired them from the official translated version of the STAIC.

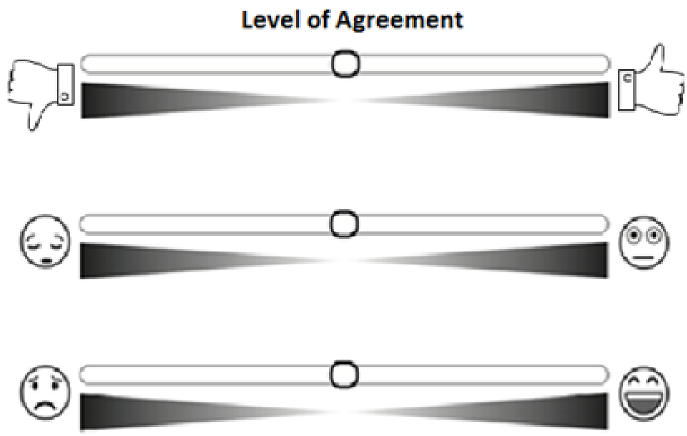


Figure 6.4: The tablet questionnaire included sliding bars and icons for level of agreement, arousal level, and mood.

In addition to the active state and STAIC questions, we also added questions about their experience playing the game. In writing these questions, we paid attention to the use of sensory details, such as “Do you remember a moment when you talked to or discovered something with your partner?” We also used the Fun Toolkit as a model for some questions. In the same fashion as the Again-Again Table, children had to choose which activity they would prefer to play with friends, between our system and a playground.

Finally, we used the questionnaires as a way to correlate events in the physiological indicators of the children with their experience in the game. For example, we asked children to touch the picture of their favorite game character. Then we asked them how active they felt when that character appeared. This, along with the anxiety inventory, was meant for cross referencing with physiological measurements and used to evaluate whether children could accurately perceive their own active state.

6.4 Physiological indicator implementation

After running an initial set of exploratory sessions with the Lands of Fog system, we identified a positive increase in social behaviors by the players. This fell in line with our hypothesis for the system, which stated that positive social interaction attitudes would be observed between the child with ASD and the typically developing child during the sharing of the experience. Although this increase in social behaviors was positive, we then began to wonder what parts of the play experience had produced this increase in social behaviors in the system. Were the children feeling at ease and open to explore the system, or did the increase result from a need to identify their surroundings in a new environment?

Also, we had seen that some design decisions would lead to an increase in social behaviors through obligating the players to work together, or enforcing their collaboration (see Encouraged and Enforced Collaboration section in Chapter 5). In reaction to this, the question was asked whether it would be better to let the players decide on their own when to interact with their partner. How could we prove that encouraging players to choose their own moments of collaboration put players at ease?

These questions formed the basis of our motivation to implement physiological indicators in the Lands of Fog system. The development of the physiological sensing devices and the posterior data analysis was carried out as part of the thesis of Batuhan Sayis. This section will describe the process of adapting the Lands of Fog experimental protocol to include this data set and the accompanying rationale.

In order to see how the experience affected the children's anxiety level, we took a baseline level of each child's active state while relaxed, and later compared these measurements to the child's active state while playing Lands of Fog. An experimental protocol was designed to look for changes in arousal level when children were engaged in social moments with their playing partners, as was identified through the video coding of sessions.

In deciding which physiological measurements to record, our primary challenge was the active nature of the game and the risk it posed to reliability of the data. We aimed to choose a measure which could be reliably gathered from players who might be running, gesturing, building with LEGO and holding interactive pointers. We first decided to use heart rate variability as one physiological indicator, which had already gathered a substantial body of research to support its reliability in movement based game settings. We then chose as the second physiological marker electrodermal activity, or EDA. These two measurements would allow us to gather a picture of the children's active state, from which we believed we would be able to infer an anxiety level. However, with current physiological measurements, feelings such as anxiety cannot reliably be identified. It is only with the addition of facial indicators together with physiological markers that we would be able to deduce the anxiety of the players. As the players were to be moving around in a dark environment, we decided that it would unreliable to deduce their anxiety levels from facial screenshots which were only partially visible. Therefore, we limited our physiological investigation to the children's arousal level, and not their anxiety level.

After choosing the physiological devices that we would use in our system, we selected the model of the device as a Biosignalplux, which would allow for wireless transmission of measurements. We then sought to design a method of placing the sensors so that they would not impede the free nature of the full-body interactive experience. Therefore, we conducted a series of usability studies with the technology to identify the best placement of the sensors. We limited our investigation to sensor placements which were recommended by published studies, including on the interior of wrists, on the upper chest, and back of the neck. Usability trials included attaching the sensors to human subjects who would then carry out a series of movements common to the gameplay experience, such as holding the net parallel to the floor while walking or running in circles. From this, a wearable was designed which would allow the children to wear the sensors while playing in the environment. The kids regarded this object with some curiousity during experiments, and after researchers demonstrated on themselves how it could be worn without harm, most of the children did not mind wearing it as part of the trials.

The physiological device did allow for collection of data during trials, although we ran into a few barriers worth mentioning. The first set of trials took place during the summer months in Spain, and many of the children arrived to the afternoon trials having perspired from walking outside. This caused problems with the EDA measurements, which relied upon the conductivity of the skin to report arousal state. To counter this problem, we mounted a thermometer in the laboratory space and only ran trials if the temperature was below an agreed threshold. Also, the audiovisual effects of the system resulted in an extreme arousal for a minority of the children, who engaged in behaviors such as running, jumping, and rolling on the floor. This caused the sensors to fall out of place, affecting the reliability of the measurements. Finally, as the trails lasted for an hour and 15 minutes on average, some children started to squirm in the second half of the sessions.

Taking measurements of the physiological states was meant to better understand the children's experience while playing with the interactive systems. Additionally, as we had been using questionnaires in previous experiments as a method of gathering feedback, we also wanted to understand the accuracy of self-report of active state in kids with autism and typically developing children. To do this, we aimed to record the children's arousal level while they completed a self-report questionnaire of their anxious state at that moment, as reported in the State-Trait-Anxiety Inventory for Children. This allowed us to understand how accurate the self-perception of their own anxiety level was.

6.5 System Log Files

In the development of the interactive systems mentioned in this thesis, one principal design element was to identify the state of the user based on behavior in the game, and have the system respond accordingly. Examples of these types of behavior include a player who is extremely passive or very active in the system. When the system recognized these playing states, it would respond with corresponding stimuli. For example, if a player was very passive, the system would respond with gentle prompts to interact with the other player, or create interactive elements within reach of that player (see system design description in Chapter 4). The idea behind this mechanism was to help pace the game to keep up with player actions. However, through the implementation of detailed system log records, we were able to make additional use of this data.

Along with the actions created by the system during each phase of gameplay, we also implemented log markers at crucial moments in gameplay. This basically meant that the system would send a message whenever players reached a milestone during play, such as successfully collaborating or coming into close contact with another player. After each session, all of these messages were recorded on the system's log file. As each session produced one log file, we were able to view the session at a glance to know how the game had advanced in terms of game actions completed.

Information from the system logs included position data of the two players, which was collected at every frame. We also could see the second when players discovered each new interaction with the system. In the Lands of Fog game, we could identify the moment when players started catching flies, got their first creature, shared their creature with another player, merged creatures with another player, and manipulated the interactive elements scattered through the virtual environment.

With the use of system logs, we were able to analyze questions such as, "How did the distance between players change through the session?" This could be done by isolating the distance between player positions during a time window at the beginning of the session and at the end of the session, and comparing the measurements. With system data, we also looked into which interactions were most transparent to players (those which they engaged in first), and which ones were only identified at the end of the session. We were able to see the number of actions completed by players and link the game actions to the social events noted during video coding.

After we added physiological reading to the system, we needed a way to mark the beginning of the session. With the help of a universal indicator, we could synchronize the information collected through video recordings, physiological indicators, and the system logs. To do this, we added a hotkey that would be recognized by the system. When the game began, we pressed the hotkey and a message was recorded at that moment in the log file. This also initiated an audible "beep" that could be heard on the video recordings, which indicated the point at which the videos would be cut to begin the session. At this moment, a note was written on the physiological recording file with the global time of that moment in the session. This would allow all three methods of time sensitive data to be synchronized.

The idea behind using the system logs to generate a timeline of the session was that this method of recording system events was more objective than the data produced by video recording and subsequent codification. While video coding produced a vision of the system in terms of social events and player actions, it had to be produced by trained coders and was subject to human error or interpretation. There was also a subjective component to the data gathered from questionnaires, as self report is vulnerable to biased results. We tried to counter these limitations by gathering data through system logs, which minimized the risk of altered data due to human subjective bias. The recordings we made could be further analyzed to see which player was leading and which was following in movement through the interactive game space, to back up our subjective observations.

6.6 Summary

The idea to collect data from multiple sources was intended to increase understanding of the children's reactions and social behaviors after the feasibility testing of Lands of Fog. For example, having a time-stamped recording of both social acts and system data helped us to understand which events from the system had led to social behaviors in the children. Because this analysis was dependent on timing of the events, we created a detailed video coding methodology which could provide information on the social acts created and the moments in which they occurred. This was necessary as no scheme was available which allowed for coding social behaviors in an ambulatory virtual environment, which was specifically adapted for children with autism. With the novel coding scheme, it was possible to compare the experiences of the children as they worked with a partner in the Lands of Fog system to the non-digital control condition.

In addition, the idea to use physiological indicators led to the development of a biosensor-fitted wearable adapted for ambulatory settings and acceptable to children with autism, which was the result of a detailed usability study. The use of this wearable allowed for the triangulation of data on the active state of the children while playing in the system. When combined with questionnaires, the combination of these data sets also allowed for an understanding of the accuracy of children's own perception of their active state at various points in the experimental protocol.

Chapter 7

Conclusions

7.1 Introduction to this chapter

This thesis has included a look into the design process of three interactive projects for fostering social initiation in autism, analyzing how the designs have led to interactions between children with autism and play peers in the context of the interactive systems presented. In Chapter 2, we provided an overview of previous work completed in full-body interaction environments and digital interventions for autism, and identified gaps in knowledge that helped to define this thesis. Methods were presented in Chapter 3, and in Chapter 4 we described the design of three experimental studies, providing corresponding procedures and results. In Chapter 5, we discussed the interaction design principles which guided the development of these systems, and how these principles can be implemented and improved upon. In Chapter 6, we discussed contributions in the evaluation methods undertaken in the corresponding experimental practices, and their adequacy for collecting multimodal data sets related to social behaviors and active states of child users with autism.

In this final chapter, we will generalize the findings presented in the previous chapters through a discussion and summary of contributions to the field of full-body interaction design for autism. The chapter will conclude with limitations and future work based on the work done in this thesis.

7.2 Discussion

The following discussion will build upon the results presented in the preceding chapters, structured upon relevant lessons from the three projects developed in this research.

7.2.1 Lands of Fog project

The Lands of Fog system was designed to be a collocated virtual environment, so that users would be able to practice socialization face-to-face in real time while playing. As mentioned in Chapter 4, results demonstrated an increase in social behaviors over the course of the sessions. Therefore, we learned that designing virtual environments where children with ASD have the ability to play with a typically developing partner can be successful for fostering social behaviors.

The use of a “peephole” effect by parting the fog was described in Chapter 4 as a design strategy put in place to help children concentrate on relevant information. This reduced the risk of overwhelming players with distracting amounts of information that could be presented in the large scale projection. As results indicated a decrease in distance travelled over the course of three sessions, it is possible that the fog motivated exploration, as during the first session the children were more actively exploring the environment which was partially obscured by the fog.

Results indicated that hunting insects was a simple introductory mechanic which children easily understood. The use of a simple introductory mechanic might have been successful in making children engage more with the system, as results show an increase in children’s activity over the course of the sessions. Slowly building the complexity of the interactions helped maintain the interest of children, in addition to serving as an opportunity to spark conversation between the two players.

Figure 7.1: The encouraged collaboration dynamic aimed to offer incentives when players collaborated.

After children gained a creature, their creature generated opportunities to collaborate and opened access to richer interactions with more exciting feedback. This approach, which we called encouraged collaboration, aimed to offer incentives for collaboration (see Figure 7.1). Results showed that children responded positively with engagement in collaborative play. We believe that with a well-thought design, it is not necessary to enforce collaboration, thus giving users freedom to continue with solo play, but still achieving positive results in positive collaboration attitudes.

Further research should focus on evaluating specific design mechanics implemented and how they affect user behavior by controlling them as independent variables. Furthermore, it is necessary to develop an experimental plan with an extended time frame to see the effects on behavior in the long term with a bigger population.

7.2.2 Lands of Fog 2 project

As mentioned in Chapter 4, we saw that system log files revealed that collaborative game events coincided with social initiations at a higher rate than events triggered by only one child's actions. This leads to the understanding that children working together on a common task might provide an opportunity for the children with autism to initiate conversation with their partner.

In this project, we expanded upon the encouraged collaboration strategy developed during the first version, rather than the habitual enforced collaboration [Crowell et al., 2019]. We believed this would provide more freedom to children with ASD in adapting to the new situation by finding their own tempo in approaching the non-ASD peer. It has proven to be a useful strategy since children only collaborate when they wish and in the meantime they can still do fun activities. This is in contrast to other multimedia applications in which the children can only perform activities as long as they collaborate (enforced collaboration).

In addition, we saw that instances of creatures greeting the other player occurred more frequently after the children's social initiations than before. As creatures greet one another when the children get close to each other, we can assume that some social initiations led to decreased distance between players. As the game bases the collaborative interactions upon joint actions, we can understand that children's proximity was a factor in fostering initiations. This tells us that we should design interactions to bring children in close proximity with one another. Since the physical dimensions of the system are considerable, with a 6 meter in diameter circular projection, we should work on designs that increase the children's curiosity towards objects or effects that can make them move toward each other.

The video coding of social behaviors revealed a higher level of non-verbal behaviors in the Lands of Fog condition than in the LEGO condition, as mentioned in Chapter 4. As the most common non-verbal behaviors were tagged as "Close Proximity," we might assume that the large physical space in the Lands of Fog setting led to a higher importance of locomotive actions and bodily gestures (non-verbal communication). Hence, players would accomplish collaborative actions by moving within close proximity of their partner, sometimes coming from across the play arena. In this case, players could accomplish the joint actions without verbal communication.

We can also attribute the rise in responses at the end of the Lands of Fog session to this mechanic, as players worked with their partner to manipulate virtual props more on average during the last five minutes than during the first five minutes of the play sessions. In contrast, since the LEGO setting provided a context where players were already within close proximity to each other, constantly sharing a focal point of joint attention, the non-verbal behavior of "Close Proximity" did not appear as often (see Figure 7.2). This tells us we must put greater effort in interaction design elements which bring the children close to perform activities together in the environment. Nonetheless, this also shows that children with ASD felt comfortable with communication styles that have traditionally been defined as difficult for them, specifically, body language and gestures.

Figure 7.2: The LEGO setting provided a context where children played within close proximity, sharing a point of joint attention.

When analyzing the difference between goal-oriented and open-ended play, we saw a slightly higher frequency of children getting together to combine their creatures while in the open-ended play setting. Although the difference was not considered significant, this difference could be related to the fact that exploring creature combinations does not contribute to the goal of the game, but is more of an exploratory action to discover all of the creature combinations possible in the game. Therefore, the goal-oriented strategy might make children adopt a much more pragmatic stance in the play session. However, after analyzing the play attitudes of children with ASD, we observed that they tend to want goals to provide them with a greater peace of mind of what they are expected to do. Therefore, we have to analyze how to take advantage of the freedom that open-ended play provides in terms of exploration of a virtual environment, while still providing a set of rules to children with ASD to guide them with checkpoints of their activity during the play session.

With regard to the questionnaires collecting data on state anxiety level, we saw that no significant difference existed in the reported anxiety level of the children after playing in the two conditions. When we consider that the children with autism made an average of 11.06 initiations per Lands of Fog session and 11.56 initiations per session of the LEGO control condition, we can see that both naturalistic environments are on the same level in serving as a positive context for fostering social behaviors. However, with Lands of Fog being an ecologically valid setting regarding real life face-to-face interaction, our system probably imposes a larger effort on children with ASD to approach the partner compared to the less demanding condition that the LEGO control condition represents. The fact that the amount of initiations is similar seems to imply that our system successfully scaffolds the initiation of social acts. These positive results place our system in an excellent position to further our research and develop a new version that can be more easily deployed in school environments.

In addition to creating social initiations in the Lands of Fog condition, we also see that the children were comfortable while doing so, as seen by the similarity in their own perceived state compared to the familiar context of playing LEGO. As children could choose the moments when they wanted to play with their partner, and also had the opportunity to step back and play individually, we believe the choice to gently encourage collaboration created a comfortable setting for socialization.

Future work could compare the effect of encouraging socialization to a setting where children must socialize in order to progress in the game. The advantages we see in encouraging collaboration are: (a) children with ASD can explore the mix of physical and virtual environments with their body; (b) they can choose to physically approach the non-ASD peer up to a comfortable distance, as opposed to a construction tool set up in which the children already need to be close together; (c) they can take their own tempo in doing this approach; (d) they can collaborate with the peer when they are willing to do so.

7.2.3 GenPlay project

When carrying out design workshops with the collaborating classrooms, several teachers recommended the use of familiar graphics, such as emoticons and characters from video games. However, the experimental study comparing abstract to representational graphics resulted in a similar level of social interaction between settings. As abstract and generative graphics are more efficient to implement computationally, we see that systems based on these types of graphics hold potential for autism interventions.

As mentioned in Chapter 4, we did not find many differences in reaction to the diversity of designs which we implemented in the system, but for children with ASD, the most important factor was that the response was clear and easily readable (see Figure 7.3). Having feedback which was consistent for each time the same action was triggered at first carried the risk of leading to boredom and repetitiveness. However, for children with ASD, having consistent reactions seemed to serve as a source of reassurance. Therefore, in designing systems for play for children with ASD, consistency

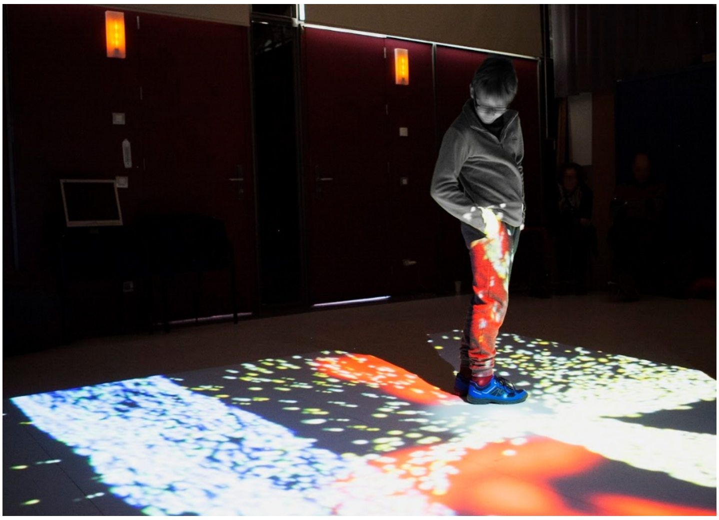


Figure 7.3: The GenPlay revealed the potential of abstract graphics in projects for ASD.

might be recommended over the search for quickly evolving features.

In the case of GenPlay, we brought consistency in the system response to joint actions by having the same system response for each instance of a repeated action. Simultaneously, we introduced subtle variations with the use of particle systems which allowed for interpolation between slow and fast movement of particles, small and large particles and a range of colors. In this way, we were able to subtly mediate novel responses with design elements while retaining a consistency in interaction and response. This same method can be used to create clarity in interactions with the system, leading to a structure which can be beneficial for children with ASD.

Thus, perhaps the most important open-ended feature was structure (see Open-Ended Play section in Chapter 5), as children with ASD found comfort in predictable responses. Therefore, as structure appears on a gradient from spontaneous play to highly-structured play [de Valk et al., 2015], designers for autism might benefit from leveraging designs towards the structured end through the use of consistent and easily-readable system reactions.

7.2.4 How takeaways can be applied in future research

Through the course of developing the interactive play systems for children with autism discussed in this thesis, we have seen a pattern that acceptance of the game seems to rely upon the structure implemented. A game does not necessarily need a defined goal, but context and structure are important factors for bridging the understanding of child users with autism (Chapter 4). This can be implemented in various forms.

Mini goals: The implementation of concrete tasks to accomplish, which do not necessarily lead to the end of play, can be useful to give a sense of progress to the players. These can help provide a sense of orientation for users to know that they are on the right path. We saw this in the structure of Lands of Fog. Even when there was no predefined goal, users discovered clear rules of the interaction and developed engagements that led them to embrace a playing style. In fact, when we analyzed behaviors made during the last five minutes of play, there was an increase in responses to their partner. This might be due to the paradigm of a large scale exploratory environment where they consistently shout or move closer to communicate once they have understood and embraced the initial structure of the game.

In one session, we saw an interesting reaction when they psychologist asked two players to get together for a moment near a virtual prop. The two girls moved together and the system responded immediately with a successful prop manipulation. Afterwards, the girls stayed side-by-side and pointed out aspects of the game to each other as they discovered things together. In this case, the clarity of the prop manipulation led to the understanding that playing in close proximity was key to the game. In addition to proximity, the immediate response and psychologist's help were important factors in maintaining the interaction.

Human Mediation: In our development of digital technologies, there was a unanimous agreement that our goal was not to replace the work of psychologists and caregivers, but rather to aid them. The training and attention to sensitive moments that the psychologists brought to our project was necessary to perceive the risk of difficult situations, such as overstimulation or unexpected physical and emotional reactions to the new environment. Present technology cannot at this time manage the delicacy of these situations. Although we witnessed almost none of these situations during all trials, it is always important to have the therapist or caregiver leading and controlling the session. Taking into account that the psychologist would be present for reassurance in the experimental setting, we set our sights on creating systems which could run independently from a computational perspective.

Having teacher involvement played a large role in child acceptance of the system when we conducted trials in Netherlands. Even when the teacher did not know enough about the system to explain how it worked, the simple presence and encouragement from the teacher served as a reinforcement to the activity.

Taking that into account, there are various levels and roles of engagement possible for a mediator, and the role of this mediator should be decided at the moment that the system is being developed. In an experimental setting, it was important to have consistency in the experiences of each participant. However, for use in a real world setting, human mediation might not detract from the socialization between players but would rather serve to reinforce the activity. It seems to support and add an extra layer of structure to the activity, so the children know that their actions have a purpose and direction.

The ideal situation would be that the children derive purpose in the activity from their own internal motivation. However, even in more exploratory contexts, children with ASD would also benefit from a predetermined structure to be coherent with the therapy practices of anticipating future events, a practice used to reduce stress in new situations. It makes sense to be consistent with the type of feedback given in therapy practices and during the game, to increase user comfort during the play experience.

The level of involvement of the psychologist or caretaker could include one of the following strategies:

- No direct involvement, only present in the experimental setting
- Sharing guidelines and/or objectives before the beginning of the experience
- Sharing hints at pre-determined points during the experience
- Present and encouraging the players, but not explaining how to play the game
- Giving tasks to complete in the game environment

Likewise, the system's role can include:

- Providing motivation through player rewards and audiovisual feedback
- Providing structure and materials for tasks
- Providing immediate and consistent feedback

An example of gradual involvement happened while testing the GenPlay system in two separate classrooms. In the case of one class, the teacher accompanied each pair of children to the classroom and gave short directions before play, then gave encouragement during play, building on their initiations. In the case of the second classroom, the teacher sent the children to the experimental setting alone. For the second classroom, only two of fourteen sessions resulted in a level of conversation considered substantial for video coding. At one point, the researcher stepped out of the room, and the children stopped playing completely and remained still in the play system. This suggests a possible link between human mediation and player engagement which should be further investigated in the context of children with autism.

A similar pattern was observed in the group sessions at the same school. In one class, the teacher did not attend the trials, sending a teaching assistant in her place. The children on the sidelines of the interactive space became increasingly disengaged in the activity, opting for side conversations and activities. In the case of the other class, the teacher attended and the child observers became involved in the activity through giving suggestions to support the two children playing in the game at that time.

This dynamic was also observed during a prototyping session of the GenPlay system at the collaborating special needs school in Barcelona. The children had played in silence during the majority of the session, when the teachers made a suggestion to the researchers to try something different. The teachers did not talk directly to the children, but rather talked audibly among themselves, narrating the actions of the children and pointing out when the children did something correctly. At that point, the children began to talk as they played, making comments about the game. Upon reflection, because the teachers normally interacted heavily with the students during classroom activities, it made sense to carry out the same trend during play with the interactive system.

Immediate and Consistent Feedback: In the development of digital technologies for autism intervention, much literature has argued for the use of technologies in interventions due to the opportunity to reinforce desired actions with immediate and consistent feedback. When we began to develop this work, our goal was to develop an interactive design that would motivate the children to carry out social behaviors with a partner. Perhaps one of the biggest takeaways from this study has not been in finding a solution, but in identifying the area where interaction design can best aid the children's play experience. Apart from design strategies of the system, creating a clear and fluid interaction design which immediately follows player actions and returns clear system responses is perhaps the biggest tool that can be used to argue for the use of these systems, as was explored through giving a sense of control to children with low-functioning ASD in the MEDIATE project [Pares et al., 2006].

In our case, the self-contained nature of the systems was meant to detect and respond to player states based on accomplishments and activity level, and could adapt the game's response accordingly. At the same time, the psychologist commented that the active nature of the interactive systems was unique in that the responses were consistently and immediately produced in a way that he did not replicate in his own therapy practices.

For example, imagine a situation where two children are playing in an interactive system. At one point, a child with ASD crosses a system-determined threshold into an area of close proximity with his partner. The system detects this slight change in positioning and triggers a response. From a human perspective, we might tend to take into account the child's intention in moving close to his partner, and upon seeing that it was not done intentionally for social contact, this behavior would not be reinforced. Therefore, opportunities for reinforcement of desired behaviors could be missed from a subjective interpretation of events. Even in the event that the children did not consciously trigger this event, they quickly become aware that their actions and positions are relevant in the scenario, and that they are the active agents of the environment around them. In the case of an interactive system, an objective response to player behavior can lead to the reinforcement of behaviors and presentation of collaborative scenarios which might otherwise be missed, which can serve to give children a sense of control over their surroundings.

In the case of passive, non-computer mediated play settings such as LEGO, this concept of an immediate and measured response is nonexistent. A correct encouraged interaction design would deliver a graduated response of the system which is proportional to the desirability of the player responses. In the case of Lands of Fog, the capturing of insects garnered a very clear response, and was consistent with the action of capturing insects in real life.

Cultural Forms: The use of cultural or real life metaphors of interaction is an idea which has been used in the field of interaction design to create natural actions [Polaine, 2010]. These cultural referents can be combined with a graduation of system responses to create a hierarchy of interaction with the goal of emphasizing desired behaviors. The clarity, immediacy, and naturalness of these actions led to the prominence of this action over all others. In our case, hunting fireflies is one such cultural referent or cultural form as defined by Horn [Horn, 2013]. In fact, players caught fireflies an average of 45 times per 15-minute session. In this case, the "intuitiveness" of this action might be broken down into three factors: *clarity*, *immediacy*, and *naturalness*.

- Clarity: The insects changed color from yellow to the color of the player's assigned net, and remained in the player's area for a short duration afterwards.
- Immediacy: The capturing of the insects was an animation which took less than one second to carry out, compared to when players merged creatures, which could take up to 10 seconds to carry out.
- Naturalness: Capturing insects with a net was a culturally inherited gesture, and the ergonomic design of a handheld net reinforced this action. In addition, the physical play notion of "chasing" is readily understood in many forms, from children playing tag on the playground to a dog chasing a ball on the terrace. The simplicity of pursuing a desired object transferred into the embodied context as an intuitive response to swarms of insects meandering through the fog, and allowed the designers to accomplish the goal of introducing the concept of movement through the interactive space.

Together, the implementation of these components led to an intuitive interaction design which could be embraced by the children.

7.3 Contributions

Although previous work had explored the use of virtual environments to simulate social scenarios, we found that full-body interactive environments developed for the practice of social behaviors, and corresponding comparison studies to traditional therapy practices, were missing. Therefore, the work in this thesis included the design, development, and testing of three full body interactive environments for autism.

In addition to the contributions presented in this section, a complete list of publications can be found in the following chapter.

7.3.1 Developed Projects and Results

In developing the projects in this thesis, we focused on the research question: *How can we improve the understanding and adoption of social behaviors and heighten inclusion with peers and society in general through the design of full-body interactive systems to aid in intervention strategies for children with ASD*?

From this, we first focused on the design and development of the full-body interactive environment Lands of Fog. The system was created to evaluate how this media could foster social behaviors in children with autism playing with a typically developed peer. In an initial feasibility study, we responded to the hypotheses:

- Hypothesis 1: ICT full-body technologies in the form of a playful experience will motivate children with ASD to play in these virtual environments.
- Hypothesis 2: These full-body interactive experiences will increase the propensity of each child to engage with other people.
- Hypothesis 3: These full-body interactive experiences will achieve positive visible social interaction attitudes between the ASD child and the typical child during the shared experience.

From the initial feasibility study, we saw that children with autism did increase social behaviors over the course of three sessions, and that parents reported that their children displayed a higher than habitual flexibility and activity level while playing in the game (Chapter 4).

To test the internal effect of encouraged socialization in a full-body interactive environment for ASD, the system was fitted with physiological sensors to understand changes in the childrens affective state. From this study, we improved our understanding of how to develop physiologically sensitive environments for autism and that, if well integrated into the context of the setting, children do not particularly mind wearing the sensors for short timespans.

We also developed goal-oriented and open-ended versions of the game to understand the effects of goal oriented play on collaboration patterns. We saw that children interacted with their partner similarly in the goal oriented and open-ended versions of the game, and there was no significant difference game actions between conditions. In particular, we saw that children engaged in the action of hunting fireflies more frequently in the goal oriented setting, which could be related to a desire to progress in the game. In the open-ended setting, children merged creatures more frequently, which was an action that did not contribute to a final goal. When an outlier session was removed, there were more social acts in every case of the goal oriented condition of Lands of Fog.

Finally, we ran a comparison study with 18 pairs of children, aiming to understand how the system could compare to a non-digital intervention tool, namely, LEGO-based therapy activities. We saw that Lands of Fog and the LEGO activity were largely similar in the frequency of social acts created by the children, although non-verbal interactions played a more important role in the Lands of Fog setting.

In the GenPlay project, we aimed to introduce the Lands of Fog medium into a setting familiar to the children to explore practical uses of the technology, outside of the therapy context. As a result of a contextual inquiry study, it was seen that children with autism could benefit from an activity related to their interests, outside of the unstructured activities which take place during recess, and that technology could be a good motivation to engage in the activity with peers. From this, we developed the full-body interactive environment based on collocated interactions found in Lands of Fog, where children could collaborate together with classroom peers.

When a version containing abstract visuals was compared against a version containing representative visuals, teacher reports revealed that the social and collaborative behavior of children with ASD was generally higher in both conditions than in their habitual, everyday interactions. The results of this study provided clear and consistent evidence collected from different sources (system data, video recordings, questionnaires) that the choice of abstract or representative graphics had no significant effect on socialization in children with ASD in the experience that was designed in the study. As seen in the study described in Chapter 4, these results placed abstract visuals as a viable alternative to be used in IT projects for children with ASD.

From this study, we broadened our knowledge of the reception of open-ended play environments with children with autism, specifically with regard to the structure necessary to help the children feel comfortable with a non-narrative structure. It was also seen that the reduced interaction space limited individual exploratory behaviors, and that a more robust tracking technology was necessary to follow the rapid movement of users through the scenario.

7.3.2 Interaction Design

Next, we analyzed the systems in light of various interaction design components to better understand which aspects of the design had led to social behaviors.

We aimed to answer the question: *How can we better understand the interaction design aspects which create socialization, collaboration, and engagement in interactive games for ASD, such as encouraged collaboration, proxemics and open-ended play*?

We developed an understanding of the concept of encouraged collaboration within the gradient of enabled and enforced collaboration, and proposed that this paradigm might be beneficial for leaving room for children to decide on their own to work together, while reinforcing these decisions through positive audiovisual feedback. We also provided guidelines for leveraging individual actions with collaborative ones, enticing collaboration through game space characteristics and increasing complexity of actions.

Through this study, we also compiled a list of collaborative interactions which can be useful for scaffolding collaboration in multi-user collocated settings, including human mediation, game mechanics, shared goals, joint narrative formation, user roles, free play, clear visibility of others actions, joint actions, and limited resources. We provided guidelines for the implementation of these interactions based on previous implementations in related work and in our own systems.

As part of the Lands of Fog project, we analyzed the personal space preferences of children with autism, gaining a better understanding of the variations between preferences of personal space between children with autism and typically developing children. A stop distance test revealed that children with autism prefer a greater distance between themselves and child peers than typically developed children, although this preference for increased distance does not carry over into interactions with virtual avatars. We discovered a knowledge gap in research based around the interpersonal distance preferences of children with autism, which would benefit our research as many of the collaborative actions in our virtual environments are proxemic-based.

Through a stop-distance study format, we revealed that children with autism do vary slightly in their preferences of interpersonal space when compared with typically developing children, but this variation is almost non-existent when the child peer is substituted by a virtual character (Chapter 5). This information led to inform the interaction design of the GenPlay system, in which children's position in the virtual world was represented by a bubble underfoot which changed color as they crossed into close proximity with a peer.

We also looked into the factors surrounding virtual environment employment in various settings, using a multiple phase model of interaction. We saw that in settings where peers are present, the understanding of the system is supported through inter subjective processes, as an extended story forms between participants. We saw differences between the types of social exchanges created when the children are alone in the environment, surrounded by peers, or accompanied by a teacher. We also saw that settings such as a laboratory and hospital engendered more formal interactions than museum or classroom settings (Chapter 5).

Finally, we analyzed how open-ended play can be employed in full-body virtual environments for autism (Chapter 5). Using a case study with the GenPlay system, we saw that social behaviors were common when children negotiated to try and understand the system. We also saw that social behaviors were common as children worked out their proposals for rules and possibilities in the system. It was seen that children switched between individual and collaborative play in the first phases of exploration, and that teacher feedback seemed to support the children's engagement in the system.

7.3.3 Evaluation Methods

As we searched for evaluation methods which would allow us to understand how social behaviors were linked to the design of the systems, we found a lack of tools which were precisely aimed towards the social behaviors of children with autism.

Therefore, we aimed to answer the question: *What evaluation methods can be effective for systems which foster socialization and collaboration in multi-user, spontaneous play based systems for children with ASD, designed using full-body interactive technology*?

To answer this question, we looked into the use of multimodal data collection through physiological sensing, video coding of social behaviors, questionnaires, and system data. We developed a methodology for coding videos in ambulatory virtual reality settings, based on the psychological profile of autism.

We also developed a corresponding coding scheme, based on the work of Bauminger [Bauminger, 2002] and on the psychological profile of autism. The video coding scheme allows for the categorization of social interactions based upon seven categories: verbal/non-verbal, direction, type of interaction, positive interaction, negative interaction, low level interaction, and anxiety indicators.

Finally, we tested the use of the Lenses of Play Cards: Open-Ended Play items as a categorization of social behaviors. We saw that, although the cards are not fit for use as a categorization of behaviors in their current state, the cards can serve as an adequate tool for post-reflection of design decisions.

7.4 Limitations and Future work

On the road to developing this thesis, we found a number of bottlenecks in our research. In the limited time of this thesis, we were not able to surmount some of these due to the logistic, technical and methodological limitations described below. Among the most significant of these challenges were recruiting child users, conducting longitudinal studies, and the extended time frame associated with developing new data analysis tools.

7.4.1 Logistical limitations

As our area of research focused on child users, there was no substitute for including these children in the design process and experimental studies of the systems we developed. To test our systems, we looked for both typically developing children and children with autism. In our case, the easiest way to recruit child users was to invite school groups to visit our lab and learn about our research, offering them the chance to simultaneously participate in our ongoing research efforts. However, this was not a possibility for the experimental trials of the Lands of Fog system, as we required 15-minute playing sessions between only two children at a time. It was also important that the children did not know each other prior to attending play sessions. Therefore, we searched for child participants to attend experimental trials on a one-to-one basis. Taking into account that children between 8-14 are often in the process of becoming autonomous adolescents, taking part in activities such as basketball, theater, and scouts took priority over coming to the laboratory to participate in our experimental sessions. For this reason, we held many brainstorming sessions on the best way to approach families.

In the end, it usually was not a matter of the child's willingness to participate in the experiments, but was rather a pragmatic question of how to approach the parents so that they would gain interest in our experiments. Our laboratory did not have any marketing professionals employed, so we used our best intuition about the approaches that might appeal to parents. We first distributed flyers near the university advertising a large scale video game that was free to play. Later, we reflected that many parents might be concerned about the amount of time that their children spend playing video games, and that our marketing attempt might have put them off for this very reason. We then approached parents with an offer to participate in a university study, so their children could learn about new technologies and be involved in the development of scientific activities. We also discussed the prospect of including information about helping children with autism, although we eventually moved away from this angle because we did not want to paint the child participants as vulnerable and "in need of help," but rather empower them as valuable play partners.

Although we were working with a special population of children with autism, finding families with diagnosed children who were willing to participate was aided by the dedication of the implicated families and the efforts by the psychologist involved in the project. Although there is a lower percentage of the population diagnosed with autism, these families saw an implicit and direct value in bringing their children to participate in the study. Also, due to the nature of our work, we had strong connections to the autism community and centers in Barcelona, along with the support of the experts at Hospital Sant Joan de Déu. Therefore, approaching typically developing children was the challenging part, and it was done through contacting civic centers, schools, and personal contacts. We also launched a social media campaign through a Facebook page advertising our study. In the end, many typically developing children came through personal contacts and family of other researchers at the university.

7.4.2 Technical limitations

Related to this were the practical obstacles to conducting long term trials. As part of the first Lands of Fog study, we invited the children to participate in three play sessions. This was challenging for two reasons. The first reason was related to the difficulties recruiting participants, and after we had recruited them, the high dropout rate when parents had to repeatedly come to the university after school or on weekends. We had the idea to install the system in a school or hospital, where the children would pass through during their daily routines. However, as the system footprint was quite large (8 x 8 x 5 meters), we could only install the system for a few days at a time in areas such as gymnasiums and the polyvalent room of our university, both of which were in demand for other activities. At the same time, our laboratory was built inside of an old factory, which had high ceilings. During the second phase of the project, we were very fortunate to acquire additional laboratory space, so the system could be installed permanently inside of our laboratory. Thus, we focused on getting children to attend only one session, to complete testing for a comparative study with LEGO. Although this seemed to solve to problem of setting up the system and competing for space, we were limited in not being able to conduct a longitudinal study with the system, with the same children attending long-term trials.

Therefore, the GenPlay system was created to address the problems of lack of space and difficulties convincing parents to come to the university. Practically, the system made much more sense. It could be set up in five minutes, fit inside a classroom, and could be moved on wheels from one space to the next. The project did have parts to improve, however. As the system was based on a floor projection, we needed dark spaces to see the full resolution of the game, which often involved putting black paper over windows or doors (see Figure 7.4). In Netherlands, we arrived early in the morning to cover a wall of windows with black garbage bags which had been cut into squares. At the same time, this created a sense of "intrigue" in the children who were eager to peek inside of the room and discover what type of experience awaited them. Although the system was able to fit inside of a classroom space, it did not allow much space for the children to move as they played with their partner. One advantage of the Lands of Fog system was that the space was large enough to allow for children to explore on their own and bring their partner over to share their discoveries. In GenPlay, the paradigm was different because the whole space was shared, so individual play was limited. It was more common for partners to focus on objects at the same time, or move through the scenario together. A future study might look into the way that these space configurations affect percentage of joint attention with a partner during play sessions.

7.4.3 Methodological limitations

As part of the contributions in evaluation methods, we have developed a new video coding scheme and corresponding methodology for implementing the coded data among multimodal sets of time-stamped data. This was seen as a necessary step, as we did not find a coding scheme which could provide us with the degree of detail necessary to triangulate how system events influenced our users' active state and social behaviors. The creation of the coding scheme was an unexpectedly long process, as creating a finalized version depended upon reaching an acceptable inter coder agreement score. The process of reiterating the coding scheme to reach an acceptable inter coder agreement took approximately one year and a half to complete, and

Figure 7.4: The virtual environments required dark spaces to display the floor-projected content.

was dependent upon having sufficient video recording materials of sessions to train coders. Because of the length of the coding scheme development process, we had a large delay in the data analysis time frame, which set the project back substantially. The result is a tool which future studies can implement and expand upon, benefiting from a more time efficient work flow in video coding of social behaviors created in full-body interactive environments.

7.4.4 Future work

Initially, we had the idea to create Lands of Fog and GenPlay as open-ended systems where the children could explore and share their experience with a partner. However, through the course of the studies conducted in this thesis, we saw that children, parents, and teachers alike requested structure to the design to give the children a sense of control over their surroundings. As this thesis is ending, we are creating new additions to the Lands of Fog system which will guide the children through the play experience.

To improve the current Lands of Fog experience, we are including graduated feedback before each action occurs so that children can anticipate upcom-

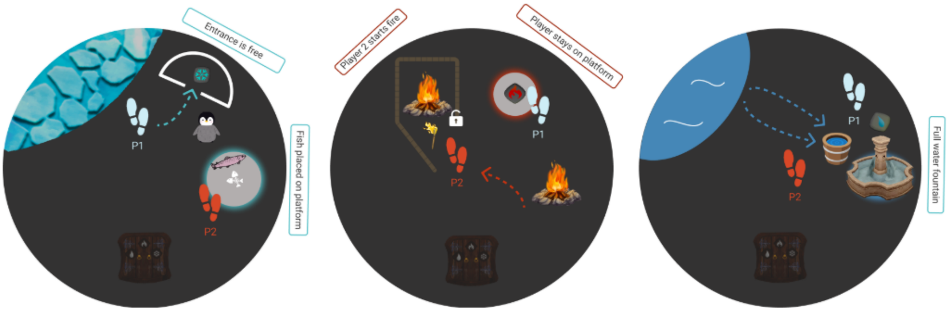


Figure 7.5: A new version of the Lands of Fog experience will include mini-goals with diversified forms of collaborative actions between two players.

ing events. This is based on the therapy practice of anticipating upcoming events with visual cues or icons. As many interactions in our games are proximity-based and we have done research into the personal space threshold that children with autism prefer (see Proxemics section in Chapter 5), we are adding visual feedback so children can see that they are approaching their partner's play area. These include particle systems which gradually build as the players get close. If the players continue to move close, these particles will accumulate into a new creature or texture change. Therefore, children can understand what will happen next and can decide if they want to continue with that action. This type of interactions worked well in GenPlay, as many children quickly noticed that their foot markers changed color as they got close to their partner. Development of the new version of the project is being led by Milagros Sevilla.

We are also adding mini-goals which utilize various forms of full-body interactive elements aside from proximity-based interactions (see Figure 7.5). Players will now push virtual stones and doors together, carry a virtual water bucket to fill a fountain, light a virtual torch, and coordinate to distract a hungry penguin who guards a valuable token. The key to these interactions is coordination between players through the use of imitation, joint attention, and user roles, all previously discussed as proposed collaboration mechanisms for children with autism (Chapter 5). These changes were inspired by an observation made during one Lands of Fog trial when the children misinterpreted the comment of the psychologist and proceeded to move side-by-side for the rest of the play session, which resulted in a high rate of social behaviors and joint attention.

As a continuation of the GenPlay project, we have submitted a grant proposal to the Spanish *Ministerio de Economía y Empresa* (Ministry of Economy and Business) to expand the current system, with the intention of increasing the social prestige of children with ASD inside mainstream classroom settings. The project will aim to improve the design of the mixed reality system based upon embodied interaction, to provide teachers in mainstream schools with a tool that can be used in the classroom for integration. The tool will be a play activity to foster social acts, particularly social initiation behaviors in the child with autism, to emerge in a natural manner during the play sessions in the virtual environment. It aims to allow non-ASD children to better understand the characteristics of autism and therefore understand that ASD classmates can be valuable play partners.

This thesis has been done with an understanding of the current state of autism research. Thanks to the valuable efforts of clinical psychologists, medical professionals, and cognitive scientists, we have more understanding now than ever before about the characteristics of the condition and the best approaches for improving the lives of those with autism. However, the cause for autism still remains a mystery, so we have based our research on the information which is currently available to the scientific community. Although our research has not included seeking the root causes or genetic origins of autism, it is my hope that the contributions in this thesis will improve the lives of some individuals, or will help to spread awareness of autism and the efforts we can make to integrate individuals with neurodevelopmental conditions into our society. Moreover, it is my desire that this thesis is not an ending point, but rather an inspiration for the work of interaction design for autism to progress in step with research discoveries, so that as we know more about the condition, we are able to do more to improve the quality of lives of these individuals and their families.

Curriculum Vitae

Biography

Ciera Crowell was born in 1990 in Georgia, in the United States. She began her studies in architecture at the Georgia Institute of Technology in 2009. In 2011, she came to Barcelona to complete her studies in architecture on exchange at the Universitat Politècnica de Catalunya. After graduation, she worked in an architecture firm in Prague and travelled the world for a year as a flight attendant. She completed her Master degree in Cognitive Systems and Interactive Media at University Pompeu Fabra in 2015. She received the award for Best Master Thesis from the Spanish Association of Human-Computer Interaction (AIPO) in 2016. She started her PhD at University Pompeu Fabra the same year, working in the Full-Body Interaction Laboratory of the Cognitive Media Technology Group. In 2018, she carried out a research stay at the Eindhoven University of Technology. This thesis is the result of her PhD research on Interaction Design for Socialization in Children with Autism Spectrum Disorders.

Publications

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4. Crowell, C., Sayis, B., Benitez, J. and Pares, N. (Under Review). A Structured Video Coding Method to Achieve Reliable Time-Stamped Coding of Social Behavior for Integration in Multimodal Evaluation: A Case in Virtual Reality for Autism. Journal of Autism and Developmental Disorders.

5. Crowell, C., Sayis, B., Benitez, J. and Pares, N. (Under Review). A Mixed Reality, Full-Body Interactive Experience to Encourage Social Skills in ASD Children: Comparison with a Control Non-digital Intervention. Cyberpsychology, Behavior, and Social Networking.

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Appendix

- Figure A.1: Initial questionnaire: Barcelona trials
- Figure A.2: Initial questionnaire: London trials
- Figure A.3: Post-session questionnaire: London trials
- Figure A.4: Tablet questionnaire: Barcelona trials
- Figure A.5: Video coding categories: Barcelona trials
- Figure A.6: Video coding data: Barcelona trials part 1
- Figure A.7: Video coding data: Barcelona trials part 2

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?

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

1b) En cas afirmatiu, a quins jocs?

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____

____

____

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

2b) En cas afirmatiu, quines xarxes socials?

____

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____

___

Figure 1: Initial questionnaire: Barcelona trials

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

Figure 2: Initial questionnaire: London trials

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

Figure 3: Post-session questionnaire: London trials

Tablet - Based Questionnaires: ASCMEOR trials	
Pre-trial (Spanish)	**Pre-trial (English)**
¿Cómo de “activo” te sientes ahora mismo?	How active do you feel right now?
¿Cual es tu estado de ánimo?	What is your mood?
¿Cómo de bien conoces a tu compañero?	How well do you know your partner?
¿Te gustaría conocerlo mejor?	Do you want to know them better?
Post Lands of Fog (Spanish)	**Post Lands of Fog (English)**
¿Cómo de “activo” te sientes ahora mismo?	How active do you feel right now?
¿Cual es tu estado de ánimo?	What is your mood?
¿Recuerdas algun momento en el que hayas hablado o descubierto algo con tu compañero?	Do you remember a moment in which you talked or discovered something with your partner?
¿Cómo de “activo” te has sentido en ese momento?	How active did you feel in this moment?
¿Te ha gustado?	Did you like it?
¿Cuál es tu criatura más memorable del juego?	What was the most memorable creature of the game?
¿Cómo de “activo” te has sentido cuando la criatura ha aparecido?	How active did you feel when this creature appeared?
¿Te ha gustado?	Did you like it?
¿Qué cosas del juego te han gustado?	What things of the game did you like?
¿Cuáles son las cosas que no te han gustado?	What things did you not like?
En comparación con el patio del colegio, ¿te gustaría jugar con tu compañero al videojuego?	In comparison to the schoolyard, would you like to play the videogame with your partner?
¿Cómo de bien conoces a tu compañero ahora?	How well do you know your partner?
¿Te gustaría conocerlo mejor?	Do you want to know them better?
¿De qué crees que iba esta experiencia?	What do you think this experience was about?
Post LEGO (Spanish)	**Post LEGO (English)**
¿Cómo de “activo” te sientes ahora mismo?	How active do you feel right now?
¿Cual es tu estado de ánimo?	What is your mood?
¿Recuerdas algun momento en el que hayas hablado o descubierto algo con tu compañero?	Do you remember a moment in which you talked or discovered something with your partner?
¿Cómo de “activo” te has sentido en ese momento?	How active did you feel in this moment?
¿Te ha gustado?	Did you like it?
¿Qué cosas del juego te han gustado?	What things of the game did you like?
¿Cuáles son las cosas que no te han gustado?	What things did you not like?
¿Cómo de bien conoces a tu compañero ahora?	How well do you know your partner?
¿Te gustaría conocerlo mejor?	Do you want to know them better?
¿De qué crees que iba esta experiencia?	What do you think this experience was about?

Figure 4: Tablet questionnaire: Barcelona trials

LANDS OF FOG - DEFINITION OF ITEMS TO BE OBSERVED:

INTERLOCUTOR:

P (CHARACTER)	When the recipient of the social initiation or response is an element of the virtual environment (character, fireflies ...). When you receive assistance from the virtual environment (eg, the character detect little activity and encouraged to follow).
A (ADULT)	When the recipient of the social initiation or response is the accompanying adult. When you receive a help from the accompanying adult.
T (THERAPIST)	When the recipient of the social initiation or response is the therapist. When you receive assistance from the therapist.
C (PARTNER)	When the recipient of the social initiation or response is the playmate. When you receive a help from another child.

COMMUNICATION AND SOCIAL INTERACTION:

SOCIAL INITIATIONS AND RESPONSES	
Integrated request	Ask for help, ask for information or to make the other do an action integrating speech and look or speech and gestures.
Non-integrated requests	Ask for help, ask for information or to make the other do an action without integrating speech and look or speech and gestures.
Integrated social initiation	Integrating speech and look or speech and gestures in order to draw attention to something, share an experience, or provide information and social commentary. ("Look at this", "How cool!)
Non-integrated social initiation	Draw attention to something, share an experience, provide information and social commentary without integration.
Integrated response	Verbal responses to interlocutor's social initiations which integrate speech and look or speech and gestures.
Non-integrated response	Verbal responses to interlocutor's social initiations which do not integrate speech and look or speech and gestures.
Non verbal response	Nonverbal responses to social initiations, requests or looks from the interlocutor.
No response	No response to the requests and questions of the interlocutor.
SHARED	
Instrumentation	Instrumental use of the other (eg, taking the hand of the other to demonstrate will do something).
Shared pleasure	Indicate pleasure or enjoyment in the interaction, not in their own activities.
Facial expressions directed at otherS	Facial expressions directed at another person with the intention of communicating emotions.
Look	Directing gaze to others in a clear, flexible and socially modulated way (to initiate, terminate or regulate social interaction).
Imitation	Copying an action of another without any purpose.
Learning of a specific action	When an action is repeated that another has done with a purpose in the game, having shown a volition to teach that specific action.
SPONTANEOUS GESTURES	
Descriptive	Gestures to represent an object or activity.
Conventional	Culturally established gestures, that have a meaning in a social purpose (clap for "well done").

Figure 5: Video coding categories: Barcelona trials

ASCMEOR: Video Coding Data

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Init_tot	,136	16	,200*	,951	16	,506
Init_first5	,181	16	,167	,916	16	,146
Init_last5	,149	16	,200*	,949	16	,470
Resp_tot	,093	16	,200*	,960	16	,666
Resp_first5	,171	16	,200*	,969	16	,816
Resp_last6	,127	16	,200*	,968	16	,805
Exter_tot	,223	16	,032	,876	16	,034
Exter_first5	,178	16	,186	,949	16	,469
Exter_last5	,273	16	,002	,773	16	,001
Highlevel	,123	16	,200*	,970	16	,840
Lowlevel	,392	16	,000	,708	16	,000
Verbal	,144	16	,200*	,918	16	,157
Nonverbal	,168	16	,200*	,929	16	,236

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

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Verbal_LOF	20,12	17	16,579	4,021
	Verbal_LEGO	23,24	17	16,791	4,072
Pair 2	NonVerbal_LOF	4,88	17	4,662	1,131
	NonVerbal_LEGO	2,76	17	3,270	,793
Pair 3	Verbal_LOF	20,12	17	16,579	4,021
	NonVerbal_LOF	4,88	17	4,662	1,131
Pair 4	Verbal_LEGO	23,24	17	16,791	4,072
	NonVerbal_LEGO	2,76	17	3,270	,793

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	LowLevel_LOF	7,59	17	3,675	,891
	LowLevel_LEGO	7,71	17	4,455	1,080
Pair 2	HighLevel_LOF	10,71	17	12,287	2,980
	LowLevel_LOF	7,59	17	3,675	,891
Pair 3	HighLevel_LEGO	12,82	17	9,382	2,276
	LowLevel_LEGO	7,71	17	4,455	1,080

Figure 6: Video coding data: Barcelona trials

ASCMEOR: Video Coding Data

Initiations						
	LOF			LEGO		
	Total	**M**	**SD**	**Total**	**M**	**SD**
Total Initiations	185	11.06	8.73	199	11.56	7.55
Initiations first 5	101	5.81	6.00	106	6.13	4.33
Initiations last 5	84	5.25	3.87	93	5.31	3.93

Responses						
	LOF			LEGO		
	Total	**M**	**SD**	**Total**	**M**	**SD**
Total responses	127	6.61	5.48	131	7.83	5.11
Responses first 5	43	2.50	2.28	73	4.33	3.12
Responses last 5	84	4.11	4.55	58	3.50	2.79

Externalizations						
	LOF			LEGO		
	Total	**M**	**SD**	**Total**	**M**	**SD**
Total responses	109	6.89	5.86	106	6.61	6.72
Responses first 5	57	4.00	4.10	48	3.17	3.76
Responses last 5	52	2.89	3.14	58	3.44	4.45

Figure 7: Video coding data: Barcelona trials