Designing Tabletop Environments for Preschool Children’s Fantasy Play

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Abstract of the Dissertation

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PhD in Informatics

“Developing Tabletop Environments for Preschool Children's Fantasy Play”
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Fantasy play is when children explore and travel through time and space, to interpret experiences into stories and to act them out. Children love this kind of play and it is really important for developing skills which will be used later in life. Today, computers are increasingly present in children’s lives, and the development of technology over recent decades has changed the way children play. This thesis explores the possibility of young children (aged 3-4) enacting their fantasy play in a virtual environment. Three different games were designed and implemented on a Mitsubishi DiamondTouch (DT) multi-touch interactive tabletop. Three evaluation studies were conducted and the performance of the children’s fantasy play was examined. In each study, children were recruited from a local preschool class.

The first study was designed to compare fantasy play in physical and virtual settings. Children from the preschool class in a state primary school were invited to play with both a real tree house and its virtual implementation on a Mitsubishi DiamondTouch (DT) multi-touch interactive tabletop. Overall, the children played quietly and alone. The results evinced several problems in the interaction with the tabletop as children struggled to drag the objects displayed on the table surface. Therefore, the study did not provide conclusive evidence of a distinction in fantasy in physical and virtual environments.

The second study was concentrated on testing solutions for the interaction difficulties evinced in the first study. A new application named The Magic House was developed and implemented on a Mitsubishi DT multi-touch interactive tabletop and tested twice with the preschool children. The results showed that most of the interaction problems from Study 1 were eliminated; evidence of more fantasy play was captured, and children played more confidently in the second evaluation session.

The third study was designed to investigate and to compare children’s fantasy play in physical and virtual settings. A new physical setting and the virtual implementation on the Mitsubishi DT multi-touch interactive tabletop of materials named The Farm were designed and examined with a group of preschool children. The results revealed that high occurrence of fantasy play was observed in the virtual setting and several similarities and dissimilarities between the two settings was also highlighted.

Overall, this thesis produced knowledge on how the application on the multi-touch interactive tabletop environment was designed and evaluated with preschool children. The thesis results demonstrate that appropriate interaction design of virtual environments could stimulate preschool children’s fantasy play and the tabletop can be operated by children as young as three. This thesis also specified requirements for designing and facilitating tabletop environments for preschool children’s fantasy play.
Declaration

I hereby declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.
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The Author

Evi Indriasari Mansor was awarded a BSc (Hons) in Information Technology from the Universiti Teknologi PETRONAS (Malaysia) in 2002. In 2004 she graduated from the University of Sussex with an MSc (Distinction) in Multimedia Applications & Virtual Environments.

The work reported in Chapters 2, 3 and 4 has already been published, although the content of these papers has been re-interpreted and rewritten for the thesis.

The selected literature review reported in Chapter 2 was published as Mansor, E.I. (2007) 'My world(s)': a tabletop environment to support fantasy play for kindergarten children. Proceedings of the 6th International Conference on Interaction Design and Children (pp. 193-196). Aalborg, Denmark: ACM.

(refer to Appendix 1)

The selected results of Study 1 reported in Chapter 4 were published as Mansor, E.I., De Angeli, A. & de Bruijn, O. (2008). Little fingers on the tabletop: A usability evaluation in the kindergarten. 3rd IEEE International Workshop on Horizontal Interactive Human Computer System (TABLETOP) (pp.93-96). Amsterdam, Netherlands: IEEE.

(refer to Appendix 2)

The selected results of Study 1 reported in Chapter 4 together with the selected results of Study 2 reported in Chapter 5 were published as Mansor, E.I., De Angeli, A. & de Bruijn, O. (2009). The Fantasy Table. Proceedings of the 8th International Conference on Interaction Design and Children (pp. 70-79). Como, Italy: ACM.

(refer to Appendix 3)
This thesis is dedicated to my beloved and wonderful mother, Allahyarhammah Elita Syariff, my dad, Mansor Chik, my handful and true-love husband, Mohd Salihan Ab Rahman, my little gorgeous princess, Ardini Dayini Mohd Salihan, my brothers, Andry Suhermanto Mansor, Mohd Firdaus Mansor and Hendra Setiawan Mansor, and my family and friends.
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1 Chapter 1: Introduction

This first chapter introduces the research work presented in the thesis. The chapter starts with the introduction and explains the motivation for pursuing the research. It defines the research questions and contributions, as well as describing the research background. Finally, it summarises the structures of the thesis.
1.1 Introduction

Children in modern society are growing up in a technological era where it is expected that they become "masters" of interactive devices from an early age (Marcus, 2006). Technology plays a significant role in our daily lives as people rely on it in the workplace, home and, increasingly, in educational settings which provide children with opportunities for engaging in activities associated with computers (Verenikina, Harris & Lysaght, 2003). In the UK, government and others have seen the potential of computers to improve the quality and standard of pupils' education as well as to support teachers' roles in the classroom (Plowman & Stephan, 2005). In the early 1980s, the use of computers was relatively new and it was not a compulsory requirement under the UK National Curriculum for children under the age of five (preschools) when it was first introduced in secondary and primary schools (Bilton, 1996). However, almost every preschool in the UK today has a computer in the classroom which is accessible for children to play with. As children are more exposed to computer technology, it is important to take into account how the technology could support them in ways that are sensible for them as avid technology users (Druin, 2001). For the last 20 years, it has been the primary concern of the Human-Computer Interaction (HCI) community to investigate ways of understanding users of technology. However, with preschool children as users, there is currently a lack of findings in understanding the children's abilities and interest as a requirement for informing and enhancing HCI investigation and design. This thesis aims to bridge this gap by a design-oriented project aimed at investigating how fantasy play can be supported in a tabletop environment and what are the main differences between real and virtual toys to elicit fantasy play.

1.2 Research Motivation

Over the last two decades, technology has changed the way children play, and toys are being replaced by other activities such as computer games. In the past, toys were made from natural materials such as wood, stones and plants; modern toys are more likely to be made from cloth and plastic. Currently, many of today's computer-mediated tools are attractive and equipped with advanced features and interactive responses. In addition, a wide variety of interactive CD-ROMs and software has been designed and is available in the market for children to play with. However, even though children enjoy playing with computers; current products do not necessarily support their imagination.
Researchers at MIT raised the issue almost a decade ago to overcome the conflict between creativity and electronic games, as they acknowledged the risk of leaving the “children as passive consumers of adult conceptions of childhood” resulting “in play that is driven by the toy rather than the other way around” (Cassell & Ryokai 2001). Regardless of a growing interest in designing technologies which fit the needs and unique requirements of children, how to support creativity, imagination and fantasy with electronic toys and tools is still largely under-explored. This knowledge gap is even wider where preschool children are concerned, in spite of a broad corpus of developmental psychology.

Early-childhood psychologists and educators know the significance of play in children’s lives (Berk, 2009; Harris & Butterworth, 2002; Verenikina, Harris & Lysaght, 2003). Play is what children always do. When at play, children are busy and enjoy themselves. Play brings happiness and satisfaction, which is important to children’s growth and development. The following scenario is an example from a dyad; Anne and Ben enjoy their playtime together at the nursery, fantasising their imaginative play with the toys.

Anne (3½ years old) & Ben (3 years old) playing together at the corner of the nursery class.

Anne: I’m the doctor (wearing the white coat and stethoscope). You be the nurse. Pretend our patient (the teddy) is poorly and we need to check him (puts the teddy on the little toy bed and covers it with a small cloth).

Ben: No. I want to be the doctor as well. Now, we are in the operation room. The nurse will help us (puts another doll next to them).

Anne: He needs an injection to reduce the pain (injects the teddy with the toy needle).

Ben: Do it nicely. Don’t hurt him!

Anne: Don’t worry. I’m the nicest doctor in the world!

Fantasy play generally can be seen as part of children’s play. It is a spontaneous and unstructured activity involving imagination and creativity, which occurs when children move from the real into an imaginary world, and play with things that are not really there or could not really happen (Goldman, 1998). Piaget referred to this activity as “symbolic play” (Harris & Butterworth, 2002). This form of play affords children the opportunity to experiment with different events, experiences and possibilities in their lives. Children begin to understand and learn how things work and what things are for through imitating things around them. Examples include dressing up and role play, making a cake from sand, constructing an imaginary house from an empty box, using
a theme to act out roles (e.g. journey to space, visit a zoo) or pretending to be something else or having a friend who is not there.

Both modern and classical theories of play recognise the many ways in which fantasy play is important and may help to develop cognitive, language, social and emotional activities (Berk, 2009; Verenikina, Harris & Lysaght, 2003). Fantasy play can be a powerful tool for children to explore and act out their knowledge about the real world. For instance, feeding the baby doll with the toy bottle helps children experience and practise caring for others without risking a real live baby. When children realise they can act out any character they want to be, their self-confidence will grow and increase their desire to explore new things. Playing also involves many problem-solving situations such as what materials or props will best support the play, and the process of looking for solutions to problems expands the analytical skills of the child, promoting creativity and abstract thinking. Children also learn the importance of communication when they are engaging in conversation with their playmates, parents, dolls or imaginary friends.

Fantasy play develops from the second year of life throughout childhood, demonstrating more complex symbolic attributions and structures as children grow older (Berk, 2009). Different types of objects can evince different types of fantasy play according to the developmental stage of the child (McLoyd, 1983). However, a natural characteristic of young children is their attraction to physical objects which can be held, touched and manipulated. Empirical research suggests that tangible interfaces could stimulate fantasy play when children interact with technologically enhanced real toys (Casell & Ryokai, 2001). However, less is known about the potential for virtual objects to elicit fantasy play, which is the main focus of this dissertation.

Although a large corpus of research has accompanied the design of tangible, desktop and mixed interfaces for virtual games, comparison between these environments is rare. A recent qualitative study led researchers to believe that physical environments may engage young children (4-6) more than desktop environments (Fails, Druin, Guha, Chipman, Simms & Churaman, 2005). The focus of the study was on learning, and the differences between the two contexts transcended the nature of the objects to be manipulated. Hence, results cannot help to understand the differences between real and virtual stimuli in fantasy play.
Chapter 1: Introduction

A further motivation for this research is that this the target user (namely, children aged 3-4) is still under-explored in the Interaction Design for Children literature, and has received little attention from interaction design researchers and practitioners. However, its importance has increased in recent years due to the diffusion of computers in homes and nurseries. When the research started (end of 2006), there were no clear guidelines available and most of the references were referred to older children. This thesis reports the results of three studies by concentrating on fantasy play in preschool children aged 3-4, aimed at investigating the degree to which spontaneous fantasy play can be elicited in virtual environments implemented on a Mitsubishi DiamondTouch (DT) multi-user interactive tabletop device.

1.3 Research Questions

The main research question addressed in the study is whether virtual objects in the tabletop environment can support and stimulate fantasy play of young children aged 3 and 4.

To answer this main question, three empirical studies were conducted and this research addresses the following sub-research questions:

1. **What are the similarities and differences in preschool children’s fantasy play in physical and virtual environments?**
   
   This research aims to investigate the nature, similarities and differences in preschool’s children fantasy play. The empirical studies are examined and reported in Chapter 4: Study 1 (The Tree House) and in Chapter 6: Study 3 (The Farm).

2. **What exactly makes children engage spontaneously in fantasy play creation with virtual stimuli?**
   
   Different objects and environments may influence the way in which children play (McLoyd, 1983). In order to understand their requirements, the researcher observed children’s behaviour while playing with the experimenter’s materials.

3. **How can the multi-touch interactive tabletop support and encourage preschool children in enacting their fantasy play?**
   
   The research investigated the feasibility of the tabletop as an interaction tool for young children.
It was hoped that the research would provide knowledge about how technology can encourage children to enact their fantasies in a virtual environment especially to parents, teachers, researchers, software designers and developers.

1.4 Research Contributions

The contributions of the thesis are as follows:

1. The thesis presents preschool children’s fantasy play in three different environments. The research shows the way children elicit fantasy play in both physical and virtual environments and how virtual environments can support and stimulate the fantasy play of preschool children.

2. The research demonstrates how young children perform their play using the multi-touch interactive tabletop device.

3. The thesis provides the requirements for designing and facilitating preschool children’s fantasy play in tabletop environments.

1.5 Research Background

The research concentrated on young children of 3-4 years old. Piaget distinguished this period of childhood as part of a preoperational stage (2-7 years) of cognitive development (Piaget, 1962). During the preschool years, children demonstrate a dramatic increase in representational activity, as reflected in the growth of particular physical, cognitive and language skills (Berk, 2009; Deloache, Eisenberg & Siegler, 2006). This group is very interesting for this research because this is the earliest stage when children start sharing and co-ordinating their fantasies with their peers (Berk, 2009). In this phase, Piaget portrays children as imperfect in the way they perform their actions, as they tend to make many errors, observe things and use simple words to describe what they see or experience (Ginsberg & Opper, 1969). They can hold only one memory at a time, and cannot yet read and write well (Bruckman & Bandlow, 2002; Berk, 2009). Children at this age become more aware of what other people are doing and try to imitate or copy them; they may have difficulties verbalising their thoughts when interacting with peers and computers. Furthermore, many of the children in this group have already been exposed to and play with computers frequently, either in school or at home. They were also capable of performing in the pilot study which was
conducted at the usability lab in the university or in the actual study which was conducted at the nursery.

### 1.5.1 Selection of Hardware Devices

Numerous hardware devices were considered in the early stages of the research with an option which:

- Could accommodate small people and the unpredictable behaviour of young children.
- Could support group collaboration.
- Could be a portable unit which easily transported and assembled for in situ testing.
- Could be available in state schools in the near future.

The early discussions focused on interactive whiteboards and tabletops. The interactive tabletop was selected as the technology solution for this research as it fitted well with the typical context of UK nurseries, where an assortment of toys and props are provided on different tables by the teacher to allow children to play and experience in a wide diversity of contexts. The use of tabletop technology or an interactive table as an input/output device is popular in the market due to the capability of the direct touch interface platform for shared display groupware. Tabletops can be used to create collaborative environments in which virtual objects can be displayed on a table surface through projection. This technology turns the table surface into a large touch screen which allows users to interact or view virtual materials with their peers in a bigger view and in a more enjoyable way. Much research has been done, supporting the view that it is easy to use, can support collaboration and offers more natural interaction styles (Apted, Kay, & Quigley, 2006; Dietz & Leigh, 2003; Piper, O'Brien, Morris, & Winograd, 2006; Sluis, Weevers, Schijndel, Kolos-Mazuryk, Fitrianie & Martens, 2004). Based on these criteria, this technology might be suitable to accommodate and support non-expert computer users, especially young children, to interact with the computer in an easier and more natural way.

The Mitsubishi DiamondTouch (DT) multi-touch tabletop was finally selected as it fulfilled all the criteria outlined above and is available at the university. Furthermore, it was expected that it would provide an easy-to-use and stimulating environment for
children. At the time of this decision (Spring 2007), there were very few interactive technologies available in the market that allowed multiple simultaneous inputs and group interaction. Also, at the time of the study there was almost no empirical evidence on the performance of young children using the interactive tabletop device efficiently.

1.5.2 The Mitsubishi DiamondTouch (DT) Multi-Touch Interactive Tabletop

The Mitsubishi DiamondTouch multi-touch tabletop is a new form of input/output device, front-projected with a large touch screen (76cm length x 60cm width) connected to a computer and a projector to display virtual objects on a table surface. The tabletop supports collaborative environments and allows users to interact with the virtual objects with their hand, finger(s) or with a conductive object with simultaneous inputs (Apted, Kay, & Quigley, 2006; Dietz & Leigh, 2003; Morris, Paepcke, Winograd & Stamberger, 2006). Pointing and drag-and-drop are the standard interaction modalities, but other complex gestures can also be implemented (Tse, Shen, Greenberg & Forlines, 2006). The DT tabletop can accommodate up to four people simultaneously; each user is provided with a separate thin rectangular receiver mat (60cm length x 30cm width), which is normally located on the user's chair. The DT tabletop transmits signals through the sensor embedded in the screen of the table via the user's body to the receiver mat. The information allows the computer to differentiate between different users; coordinates of their input identify which user is touching what and where. Figure 1 illustrates the basic components of the DT tabletop.

Figure 1: The typical Mitsubishi DiamondTouch (DT) multi-touch tabletop setting
1.6 Outline of the Thesis

This section gives an overview of the topics discussed in each of the following seven chapters of the thesis. The structure of the thesis is illustrated in Figure 2. Chapter 2 presents the literature review, and Chapters 3 explains the research approach. Chapters 4 to 6 report the empirical studies. Finally, discussion and implications of the findings for HCI research are presented in Chapter 7.

Figure 2: Structure of the thesis
1.6.1 Chapter 2: Literature Review

Chapter 2 provides a number of distinct areas of the literature review including developmental psychology, educational studies and HCI, which are relevant to the study.

1.6.2 Chapter 3: Research Approach

Chapter 3 sets out the methodology used in the research. It describes the techniques and approaches implemented by the researcher.

1.6.3 Chapter 4: Study 1 – The Tree House (Physical vs. Virtual)

Chapter 4 explains the design and findings for empirical Study 1. This chapter presents an exploration of the fantasy play performed by young children, examined by comparing fantasy play in a physical and a virtual environment. A real wooden tree house and its virtual implementation on a DT table were designed and evaluated with young children. The similarities and differences of fantasy play in physical and virtual environments were investigated. The chapter describes the method used to collect the data that forms the empirical foundation of the thesis. The results of the study highlighted several problems faced by children whilst interacting with the tabletop.

1.6.4 Chapter 5: Study 2 – The Magic House

Chapter 5 describes the design and results for empirical Study 2. It focuses on the solution to problems which arose in Study 1. The Magic House application was designed by modifying the Mitsubishi DiamondTouch tabletop settings and size reduction of the virtual objects. The chapter investigates how the tabletop could offer an engaging experience for children. It reports how data was collected and analysed. The results of the study successfully solved problems evinced in the Study 1.

1.6.5 Chapter 6: Study 3 – The Farm (Physical vs. Virtual)

Chapter 6 reports the design and findings for empirical Study 3. In this chapter, an extended comparison of fantasy play in a physical and a virtual environment is examined. A real farm toy set and its virtual implementation were designed with the modification to the DT setting tested with young children. This study investigated the
similarities and differences of fantasy play in physical and virtual settings and how children could engage in complex fantasy play creation with virtual stimuli. It describes the data collection and analysis methods used for the study. The results of the study demonstrated further evidence of fantasy play observed in the study.

1.6.6 Chapter 7: Conclusion

Chapter 7 builds on overall discussion and conclusions. It concludes the thesis by summarising the results and discussing the limitations, implications and contributions of the research to the HCI community, makes suggestions for possible directions for future research, and provides design guidelines for designers and researchers.

The following chapter will discuss in more detail the nature of fantasy play in children and the impact of computer technology on play.
Chapter 2: Literature Review

The previous chapter overviewed the potential for exploring the fantasy play of preschool children in a digital environment. This chapter will give an account of the literature in developmental psychology, educational studies and HCI towards understanding the complexities of children’s play. Its reviews the background of preschool children, fantasy play, designing, evaluating and analysing research with children and the relation of technology towards preschool children’s fantasy play.
2.1 Introduction

As described in the previous chapter, this thesis investigates the possibility of fantasy play in the virtual environment within preschool children. Therefore, it is very important to understand the nature, needs, abilities and interest of preschool children for HCl evaluation and design. This chapter will expand on this area by reviewing the literature relevant to the study of preschool children, fantasy play and technology. There are six sections:

Section 2.2 provides a brief introduction and definition of the child, describes the patterns of child development in terms of domains and periods of development, and highlights the most important theories of child development.

Section 2.3 describes the preschool child’s characteristics in terms of physical or motor skills, learning and cognition, language, emotional and social development during preschool years.

Section 2.4 provides an overview of children’s play and describing types of play.

Section 2.5 goes deeper into fantasy play in children, describing the development of fantasy, the props normally used in fantasy play, solitary and social fantasy play and imaginary companions.

Section 2.6, provides an overview of the use of computers for children's play, followed by a discussion on designing, evaluating and analysing for children, the use of technology for children’s fantasy play, and the use of the tabletop for children.
2.2 Children

Generally, a child is classified as a human being from the time of birth to 18 years old. The legal definition of a child commonly used is from the United Nations Convention on the Rights of the Child (UNCRC), composed of members from countries around the world (1989). In terms of biology and psychology, children are human beings in the developmental phase of childhood, which is between infancy and adulthood (Berk, 2009; Keenan & Evans 2009; Trawick-Smith, 2009). Children have unique characteristics, desires and needs, which vary between different age groups and from those of adults (Druin & Solomon, 1996). As children grow up, they move through stages of development and learn from their environment through experience. The rate of child development also differs from one child to another and from one group to another.

2.2.1 Child Development

Child development refers to patterns of physical, social and psychological growth changes over time which begin at conception and end after adolescence.

2.2.1.1 Domains of Development

Development occurs in three different but related domains (Berk, 2009):

- **Physical Development.** Physical changes in the body, including size, proportions, appearance, functioning of the bodily system, physical health, perceptual and motor capabilities (fine and gross).

- **Cognitive Development.** Changes in intellectual or thinking abilities, including memory, attention, daily knowledge, problem solving, imagination, creativity, language and academic ability.

- **Emotional and Social Development.** Changes in emotional and social relationships, including self-understanding, emotional communication, interpersonal skills, knowledge about other people, intimate relationships and moral reasoning and behaviour.
2.2.1.2 Periods of Development

Child development is divided into five periods, each conveying new capabilities and social expectations that serve as significant transitions in major theories (Berk, 2009).

- **The prenatal period (from conception to birth).** The process in which a foetus or an embryo develops during pregnancy, from fertilisation until birth.

- **Infancy and toddlerhood (from birth to 2 years).** The period leads to remarkable transformations to the brain and body that support the intellectual, motor and perceptual abilities. Infancy applies to children between the ages of 1 and 12 months and toddlerhood usually from 12 months to 2 years. During the toddler phase, the child starts to learn to walk, use language, and develop motor skills and social roles.

- **Early childhood (from 2 to 6 years).** The physical body becomes longer and thinner, children become self-controlled, fantasy play skills bloom, the motor skills are refined, and they improve both their language skills and their social skills with friends. During this period, children have the opportunity to go to preschool or kindergarten as their early childhood education, which normally focuses on learning through play.

- **Middle childhood (from 6 to 11 years).** This period begins at approximately primary school age where children learn more about the real world and increase the capabilities and responsibilities that they will have as adults. They master basic literacy skills, improve in physical ability, participate in games with rules, and develop more logical thought processes; self-understanding is enhanced and friendship are established.

- **Adolescence (11 – 18 years).** This period starts the transition into adulthood, which leads to an adult-sized body and sexual maturity. Thought becomes more idealistic and abstract, and education is increasingly directed towards preparation for higher education and the world of work.

2.2.2 Theories of Child Development

Child development theories are logical systems of concepts that provide a framework for understanding, organising, explaining and making predictions about the child’s growth, development and learning. Over the years, scientists and psychologists have
formulated an array of theories explaining their discoveries about child development. The following are a few of the most important theories that have emerged to explain various aspects of child development:

2.2.2.1 Behaviourism Theory

Behavioural theories of child development focus on how environmental interaction influences behaviour.

**Watson (1878-1958).** Behaviourism began with the work of psychologist John B. Watson, who wanted to create an objective science of psychology and believed that directly observable events should be the focus of study (Keenan & Evans, 2009). Watson often cited the work of Ivan Pavlov (1849-1936) who demonstrated techniques for studying reactions to the environment (Watson & Raynor, 1920). In some of his best known research, Watson applied Pavlov’s principle of *classical conditioning* (a method when a naturally occurring stimulus is paired with a response) to children’s behaviour. In the study, he taught a nine-month-old baby to fear a natural stimulus (presenting a white rat with loud sound several times) and the baby shortly learned to fear it (crying and turning his sight away from the rat). On the basis of his discovery, he believed that learning is the key factor in clarifying development and that environment is the most important aspect in child development, where adults can stimulate children’s behaviour if they carefully control stimuli and response associations or arrangements.

**Skinner (1904-1990).** B.F. Skinner proposed the *Operant Conditioning Theory* which is a form of learning behaviour that arises through rewards and punishment. Skinner believed that children’s learning behaviour could be increased with the use of the *reinforcers* concept (e.g. teacher or parent rewards the children if they complete their homework) and decreased by the use of the *punishment* concept (e.g. teacher or parent withdraws children’s privileges). Skinner’s *Operant Conditioning* has been widely applied in the research on child development (Akers, Krohn, Kanza-Kaduce & Radosevic, 1979; Berk, 2009; Keenan & Evans, 2009).

2.2.2.2 Social Learning Theory

**Bandura (1925-).** Albert Bandura proposed the *Social Learning Theory* (also referred to as *modelling*), which is the expansion of the conditioning and reinforcement introduced by Skinner and others. He believed that people could learn new behaviours and information about the reason for reward and punishment by observation and, as a
result, that they would start to understand their talents and abilities (self-efficacy) by watching and listening to others around them commenting on their behaviour (Akers, Krohn, Kanza-Kaduce & Radojevic, 1979; Bandura, 1974; Keenan & Evans, 2009). Therefore, children who are exposed to positive models are likely to build up stronger senses of self-efficacy than children who are exposed to less positive models and are likely to give up in reaction to frustration.

2.2.2.3 Sociocultural Theory

Vygostsky (1896-1934). Lev Vygostsky developed the Sociocultural Theory which concentrated on the interaction between children and society (Bedrova & Leong, 2006; Berk, 2009; Vygostsky, 1978). He believed that children’s social environment forces their development by influencing the way that they think, learn and behave, reflecting their society’s culture. Through social interaction, children continuously learn from more knowledgeable members of society such as parents, relatives, teachers or peers in shaping their knowledge, besides exploring their surroundings by themselves. The learning journey can vary from one culture to another depending on the criticism and encouragement of the environment to the child’s responses (Berk, 2009; Keenan & Evans, 2009; Vygostsky, 1978).

2.2.2.4 Cognitive Development Theory

Piaget (1896-1980). Jean Piaget studied the reasoning processes of children at various ages and he was the first to note that children play an active role in gaining knowledge of the world. He believed that children think differently from adults and begin their development by being cognitively egocentric (Flavell, 1999). According to Piaget, cognitive development is a process of adjustment of children’s knowledge to fit the reality. Piaget reviewed children’s cognitive development in four main phases (Piaget, 1962; Piaget, 1971; Piaget, 1983):

- **Sensorimotor (birth to 2 years old)**. Infants explore the real world through their senses and movements. They differentiate themselves from objects and recognise themselves as agents of action and begins to act intentionally; for example, shaking a rattle to make a noise, pulling a string to hear the sound of a music box and arranging objects in and out of containers.

- **Preoperational (2 to 7 years old)**. During this period, preschool children develop language and use more symbols to represent their earlier sensorimotor
discoveries, as evidenced by an increase in playing and pretending. However, thinking is still egocentric; that is, they have difficulty taking the viewpoint of others from their own perspective.

- **Concrete operational (7 to 11 years old).** Children at this stage have better understanding of mental operations and can think logically about objects and events. However, thinking falls far behind adults’ and there is difficulty in understanding the abstract.

- **Formal operational (11 years and above).** During this period, people can think logically about abstract propositions and test hypotheses systematically.

This research is concentrated on preschool children aged 3-4. The following section reviews the preschool’s characteristics, needs and skills that might help in understanding the world of preschool children.
2.3 Preschool Children

Preschool children are young children between infancy and school age, usually aged 3-5. They have the opportunity to go to a preschool or kindergarten for their early childhood education before compulsory education begins; this normally focuses on learning through play. Some nurseries are attached to state infant or primary schools, but many are available privately. Piaget characterises this period as part of the preoperational stage (2-7 years old) of cognitive development. Development occurs in different domains, related to each other. During the preschool years, children demonstrate a parallel and dramatic increase in physical, cognitive, language and social skills (Berk, 2009; Deloache, Eisenberg & Siegler, 2006; Harris & Butterworth, 2002).

2.3.1 Physical or Motor Skills Development

Physical development is changes in physique or body, including size, proportions, appearance, functioning of bodily systems, physical health, perceptual and motor capabilities (fine and gross). Children start to develop their muscles and movement skills when they are born. As children grow, muscles become stronger and more developed due to changes in body size, proportions and muscle strength. As the body develops to become less top heavy and more streamlined, the centre of gravity moves downward, where it help to improve the stability of the body and to support new motor skills that involve large muscles (Berk, 2009). Therefore, the motor skills of young children are less developed than those of older children and adults.

Throughout the preschool years, children develop their fine and gross motor skills to support improvements (Berk, 2009). Fine motor skills involve the small muscles controlling the hands, fingers, wrists, feet, toes, lips and tongue. For instance, preschool children are able to draw, paint, colour, write, use scissors, open and close objects, use locks and keys, make crafts, do puzzles and use a spoon while eating. Gross motor skills involve the large muscles of the body and by the time they reach preschool, almost all children are able to pedal a tricycle, walk up and down stairs, run more smoothly, skip, jump, hop, throw and catch.
2.3.2 Learning and Cognitive Development

Cognitive development involves changes in intellectual or thought abilities that manage mental activity, including attention, memory, problem solving, imagination, creativity, language and daily knowledge. Children experience the most extraordinary change in mental representation during the preoperational stage. The indication of mental representation can be seen in children's re-construction of language, fantasy play, story, drawing and painting.

Attention is the cognitive process whereby a person concentrates on some features of the environment while ignoring other things. Young children are easily distracted and only pay attention to limited information for a certain period. However, they can eventually focus for longer periods of time when they increase and sustain their attention on important information and ignore other distractions in order to complete a given task (Lopez, Menez & Hernandez-Guzman, 2005). Furthermore, according to Anderson & Levin (1976), attention in young children can increased with the presence of some visual and auditory attributes.

Memory is the ability to store, retain and remember past experience. During the preschool years, children start to develop remarkable abilities in using their memory. However, their abilities remain limited and only truly start to become more elaborate and effective in the middle of childhood (Schneider, 2002). In addition, the amount of information that they can remember is limited and generally requires a number of hints and clues for recall.

Problem solving is the ability to determine the solution to a problem efficiently. Children’s ability to solve problems experiences significant changes from the ages of 2 to 6. Bullock and Leutkenhaus (1988), who studied young children’s abilities to stack disks in order to copy a tower built by an adult, found that children aged 3 were already beginning to understand the correct solution to a problem. Children gradually engage in complex problem solving during the preschool years as they are increasingly involved in make-believe play where they are compelled to follow the rules of play. For example, a child pretending to be a teacher must act according to the rules of teaching behaviour. Indirectly, children engaging in such problem solving behaviour assist their cognitive development and understanding.
Another important skill developed during the preschool period is the ability to use analogies. Analogy is a cognitive process of transmitting information from a particular source to a particular target. Children use analogies whenever they recall a familiar piece of information and generalise it to a new situation. Goswami and Brown (1990) have shown that analogy is well established by the age of four, when children are able to sort and match items to arrange pictures or objects.

While children do make significant progress in mental representation abilities, the limitations of the preoperational stage were focused on by Piaget. An important limitation to their cognitive abilities is egocentrism, in the sense that they cannot understand a situation from another person's point of view (Harris & Butterworth, 2002). Piaget demonstrated an example of egocentrism with his three-mountains problem (Berk, 2009). In the experiment, there are three mountains (with different heights) and a doll (located opposite the child). Each mountain is differentiated by its colour and by its summit. One has a snow-capped peak, another has a cross and the third has a small house. Results from the experiment revealed that children cannot choose a picture that shows the mountains from the doll's point of view. They tend to choose the picture based on their own view.

Another limitation is centration, which is the tendency to concentrate on a single aspect of a situation and ignore others. Piaget illustrated this in his experiment on children's understanding of the conservation concept, with conservation of liquid quantity, conservation of solid quantity and conservation of number (Piaget, 1952). From the results, Piaget perceived that preoperational children are easily distracted by perceptual appearance and fail to understand that their own viewpoint can be false (Berk, 2009).

### 2.3.3 Language Development

Language is a way of communicating with other people through voice sounds, gestures, symbols and words for the expression of feelings, thoughts or ideas. Early language development starts with the simple production of words without meaning; slowly, as the children grow, words acquire meaning and are combined into simple sentences. During preschool years, children shift from their first construction of words to the commencing of word combinations (Harris and Butterworth, 2002). They begin to engage in simple sentences, improve pronunciation, use plural words, begin to
understand size relationship and colours, add grammatical morphemes and gradually produce complex grammatical structures.

Furthermore, they slowly get an understanding of rhyming and alliteration (words sounds the same at their beginning and end), blending and synthesising (breaking words apart, or combining words into new words); they use symbols and know what many symbols in the environment signify, they enjoy riddles, poems, songs and listening to stories, and they continue to learn new words and enlarge their vocabulary throughout the preschool period and school years. Children also learn more about communication through conversation. The language that children always hear also influences their language development (Harris & Butterworth, 2002). For instance, children normally used words that are used by their mother or people in their surroundings.

2.3.4 Emotional Development

Emotional development is a process of developing feelings and learning how to handle them appropriately. The basic and common emotions in humans are happiness, anger, sadness and fear, which can be evidenced in the presence of facial expression, gaze and tone of voice (Berk, 2009; Dunn & Hughes, 1998; Keenan & Evans, 2009). During the preschool years, children’s emotions are very sensitive and can change rapidly as they switch from one activity to another. Preschool children have difficulties separating feelings from actions, as they tend to express what they feel and try to get what they want. However, their understanding of feelings and emotional situations gradually improves as they begin to understand, experience and learn how to control and express their emotions appropriately, especially with their play partners because it enables them to be aware of the emotions they or another person is feeling (Ashiabi, 2000). For example, a baby may have a tantrum or get mad if a toy is taken away; but, as children grow older, they learn how to control their anger, which can be expressed in different and acceptable ways.

2.3.5 Social Development

Social development is the process of learning diplomacy to interact with people such as family and friends. Parten (1932) believed that the nature of social play and interactions changes significantly during preschool years as children become progressively more social beings and show growing interest and preferences in playing interactively with some children over others. By developing their social skills, children will be able to
respond appropriately and develop positive and solid friendships (Berk, 2009). In addition, children are able to organise and control their behaviour, grow in independence, develop empathy and understand rules and fairness. Children also learn to develop turn taking and share play skills as they offer help to each other (although their ability to describe how to do things is still less developed than their ability to show what should be done). From observations with preschool children during their play periods, Parten claimed that different types of play involve different levels of complexity and she also discerned six types of play that preschool children engaged in: the cooperative, associative and parallel as social play and onlooker, unoccupied and solitary play as non-social play (Parten, 1932; Keenan & Evans, 2009; Rubin, Maloni & Hornung, 1976). In the following, the types of play are listed from the most complex to the least complex:

- **Cooperative Play.** Cooperative play is the behaviour that occurs when children play and build things together in an organised group activity with specific role assignments.

- **Associative Play.** Associative play is the behaviour that occurs when children talk to one another and share the same materials in their play, but there is no role assignment or organised activity towards completing a joint project.

- **Parallel Play.** Parallel play is the behaviour that occurs when children playing near or next to other children use the same toys and materials or are engaged in the same activity without interacting with each other.

- **Onlooker.** Onlooker is the behaviour of a child watching other children play without joining in.

- **Unoccupied Play.** Unoccupied play is the behaviour that occurs when a child simply watches other interactions, events and objects that are of interest, without playing with anything.

- **Solitary Play.** Solitary play is the behaviour that occurs when a child plays alone, noticeably different from others.

### 2.3.6 Theory of Mind Development

Theory of mind is the ability to attribute mental states such as desires, beliefs, intentions, and emotions, and also the awareness that other people’s mental states
differ from one to another (Miller, 2006). The theory of mind helps people to easily understand their own and other's actions and to predict and control their behaviour by manipulating their mental states. Developmental psychologists believe that the theory of mind could explain human behaviour. Therefore, reaching this stage is a vital step in a child's participation in a social world. Normally around the age of 3, children are good at communicating what they want. They can also make more complex predictions about behaviour based on the concept of belief and desire, such as relating another person's actions to their beliefs and desires. However, preschool children's mental representation has not yet developed, so their perceptions and beliefs can be false (Keenan & Evans, 2009; Taylor & Carlson, 1997).
2.4 Play

Play is an interesting phenomenon in children’s lives. Play is usually seen as distinct from work and is a voluntary activity. Normally, playing children choose the content and purpose of actions; following their own thoughts and interest, in their own way for their own reasons (Else, 2009). Play is an important part of children’s life and development, allowing them to act out, develop and share their understanding of themselves, others and the world surrounding them (Ginsburg, 1969). As described by Verenikina, Harris and Lysaght (2003), “Play is not only an enjoyable and spontaneous activity of young children but it also contributes significantly to children’s psychological development”. Children’s play is not only a sign of cognitive development but it also fulfils significant functions for cognitive and social growth (Cole, Cole & Lighfoot, 2005). Developmental psychologists also agree that playing is more than just having fun, and that children learn best through play (Inkpen, 2001). By playing, children increase their ability to communicate with others, explore and test their knowledge of the real world (Moyles, 2005).

Play is a difficult concept to define. Fagan (1974) described play with two different definitions, the functional approach and the structural approach (Smith, Cowie, & Blades, 2003). The functional approach describes play as behaviour which does not have an external target or goal. If an external goal exists, such as the need to eat, the action is not play. The structural approach illustrates types of behaviour or actions that occur only in play, such as play signals. Signals of play in children can normally be seen through laughter, associated with an open mouth in their play face. However, not all play is indexed by play signals.

According to the structural approach, behaviours can be considered as playful if they are ‘repeated’, ‘fragmented’, ‘exaggerated’ or ‘re-ordered’. For instance, a child running up a slope may not be playing; but if the child runs up and slides down numerous times (repetition), runs just halfway up (fragmentation), jumps or takes large or small steps (exaggeration), or runs up and then slides down (re-ordered), those behaviours can be considered as playful. Play or playfulness can also be identified through several play criteria such as enjoyment, flexibility and pretence. One criterion is not sufficient, but the more criteria are demonstrated, the more the behaviour agrees with the definition of play (Smith, Cowie, & Blades, 2003).
2.4.1 Types of Play

Children play in many ways, from calm to active activities (Wyeth, 2006). The levels and stages of play among children are also different. Normally, their play become more complicated when they grow older as they gain in knowledge and experience (Ginsburg, 1969; Verenikina, Harris & Lysaght, 2003). There are six different types of play (Smith, 2010):

- **Sensorimotor Play.** Sensorimotor play refers to Piaget’s sensorimotor period (up to around 2 years) involving activities with simple actions on objects (or one’s own body) such as sucking objects, pushing, banging or shaking blocks.

- **Object Play.** Object play also involves activities with objects, but it is more constructive, as in making block towers, fitting lego blocks together and using modelling clay.

- **Social Contingency Play.** Social contingency play refers to simple games where there is enjoyment in the responses of others, such as peek-a-boo.

- **Language Play.** Language play can be referred to as playing with sound and words such as conversations, repeating patterns and rhymes (Smith, 2010). It begins very early and sometimes goes unnoticed, such as the repetition of certain noises or babbling. In language play, children find out the extraordinary ways in which language can be manipulated and combined, and words are transformed into playthings. As children get older, they become more skilled at using language and they use it in advanced approaches to excellent effect (Smith, Cowie & Blades, 2003).

- **Physical Activity Play.** This refers to playing with physical actions or bodily movements, often without objects. It includes actions such as kicking legs, waving arms, crawling and throwing for infants; a lot of exercise play during preschool years (involving whole body movement either alone or with others) such as jumping, climbing and running; and rough-and-tumble play such as chasing and fighting in older children (Smith, 2010). Normally play that involves physical contacts such as wrestling and chasing is indicated by laughter and smiling (Smith, Cowie & Blades, 2003).
Chapter 2: Literature Review

- **Fantasy Play.** One of the common and important plays in children’s life is fantasy play. Fantasy play is where the child plays ‘outside’ the real world (Smith, 2010; Cole & Cole, 1993).


2.5 Fantasy Play

Fantasy play is an interesting aspect of the behaviour or activities of children from around two to ten years old, involving 'as-if' or 'make-believe' elements. It is delightful to watch and is a pleasurable experience for adults to observe or overhear a group of children or a single child engaging in various aspects of spontaneous play. Fantasy play is also known as imaginative, make-believe, symbolic and pretend play; it is leisure and a spontaneous activity where children use their imagination purposely to act out imaginary activities and use real objects to stand for imagined objects (Goldman, 1998; Keenan & Evans, 2009). Examples of fantasy play are: constructing an imaginary house from an empty box, transforming a piece of paper into a flying carpet, making biscuits from plasticine and wearing a white coat to be a doctor.

Vygotsky (1978) viewed fantasy or make-believe play as unique, largely influencing children’s zone of proximal development as they are able to perform and to develop through exploring a variety of challenging skills. The zone of proximal development (ZPD) is the difference between what a child can do with help (child’s potential development level seen when the child solves problems in interaction with peers or adults) and what he or she can do without guidance (the child’s actual development). In Vygotsky’s theory, fantasy play is the key foundation of development during preschool years in two ways (Berk, 2009). First, as children enact and create their imaginary world in their fantasy play, they learn to act based on their internal ideas. Children continually use object substitutions (one object stands for another meaning) while pretending. Gradually it helps children to differentiate between objects and thinking (ideas can be used to lead actions). A second element of fantasy play is its rule-based nature, where children are encouraged to think before they play. For instance, a child imagining herself as a teacher and a doll as the student obeys the rules of school behaviour. As children act out rules in their fantasy play, they acquire better views and understanding about social roles and expectations. Research has also shown that preschoolers who engage in more complex fantasy and sociodramatic play were better at respecting classroom rules (Elias & Berk, 2002).

Fantasy play not only helps children to express, try out and explore their world with imaginary situations, but also it helps them to play with words and language. Fantasy play also gives them an opportunity to talk, imitate, negotiate and share. It is a good activity where they can learn management of emotions like happy, sad, fear, disappointment, anger and jealousy. According to one study, fantasy play is also rich
with private speech (Krafft & Berk, 1998). Private speech is when children talk out loud to themselves during their play. For instance, “I need the square one. Not this one. Here it is. Try it here”, says a 4 year-old girl talk to herself as she works on a puzzle. In Vygotsky’s theory, children speak to themselves for self guidance and help in controlling their own behaviour (Berk, 2009). Fantasy play helps children to be creative and imaginative as pretend experiences become more fantastic and complicated (e.g. pretending to be a jungle explorer hunting for treasure instead of simply being a farmer).

Singer (1973) suggests that predisposition to fantasy play is an enduring personality trait which, if allowed to develop, has uses in later life. He emphasises the need of imaginative activities to be stimulated by adults and stresses the importance of a close and stable parent-child relationship, for encouragement, initiation and modelling of fantasy play. This position was held even more strongly by El’Konin (1966) and is supported by various studies which show that fantasy play can be increased by training (e.g. Smilansky, 1968; Fink, 1976; Saltz & Johnson, 1974). Singer (1973) also states the need of privacy, freedom from interference, acceptance of fantasy play activities and availability of fantasy materials.

### 2.5.1 The Development of Fantasy Play in Children

Piaget (1962), who worked extensively with children, described details based on his experience with his daughter Jacqueline. According to Piaget, the pattern of fantasy play occurrence follows something like a U-shaped curve, beginning during the first year of life, peaking during the preschool years (3 or 4) and decreasing during the primary school years (Fein, 1981).

The initial form of fantasy play can be noticed from about 12-15 months. Most early fantasy play imitates actions using high-level structure objects, normally with themselves as an agent. For example, 18 month-old children pretend to drink from a cup together with eager drinking sounds and eat from an empty bowl using a toy spoon, or they pretend to feed a baby doll with a toy bottle (Harris & Butterworth, 2002). Piaget found that children could convert familiar symbolic actions to new actions. For example, he described how Jacqueline at 19 months commanded her toy dog to cry and she copied the sound of crying. Later she commanded her hat to cry. From the pattern, it shows that young children imitate their own acts in their fantasy play. Later on, children start using imagination and imitation. For instance, Jacqueline
at 22 months cleaned the floor with a seashell and then with a cardboard lid, having previously watched the cleaner cleaning the floor.

After the age of 2, children gradually learn to use their imagination and use a range of more low-level structure objects to symbolise something else. For example, they can use a wooden block as a cake or a stick as a magic wand. They also learn to shift from using themselves as agents of their fantasy (i.e. brushing their own hair) to acting their fantasy on others (i.e. brushing the baby doll’s hair). According to Piaget, at this stage children’s fantasy play involves a combination of complicated symbols. He described how Jacqueline at just over 2 years old held a brush over her head and imagined the brush to be an umbrella.

From the third year of life, children start realising that the agents of their fantasy play can be independent of themselves (i.e. a mother doll brushes the baby doll’s hair). At around this age, fantasy play moves from a solitary activity (children play without connection to their peers) to a parallel activity (children play individually but tend to imitate each others’ activities). High-level structure objects are still the favourite target and stimulus of fantasy play, although children are capable of engaging in more creative exploration of low-level structure objects (McLoyd, 1983). High-level structure objects afford conventional usage, whereas low-level structure objects afford substitutions or the projection of new meanings into objects (e.g. a square block is transformed into a table).

Up to age 7, fantasy play shifts from an individual type of play to a more complicated social activity. For instance, early fantasy play is usually done alone or maybe with a parent or carer as cooperating assistant or helper. Later, children start to be aware of other children’s fantasy play and copy it. Fantasy play increases steadily and becomes more orderly during the following years as a complex combination of schemes in sociodramatic play and exact imitation of reality is often performed. At about 4, well developed children may have loaded imaginative play and tend to take on a more social approach, create and combine ideas, coordinate roles and enact complex and interactive imitations of reality (Harris & Butterworth, 2002). At this stage, they build on others’ play ideas, creating and assigning several roles to peers: “I’ll be the mother and you’ll be the baby”. As the complexity enhances, children may consume more time in setting up the plan and assigning roles than in the actual play. Fantasy play becomes more social and children start sharing and co-ordinating their fantasies with others. As
they grow older, collaborative fantasy play increases while non-collaborative fantasy play decreases (Berk, 2009).

2.5.2 Fantasy Play Roles

Normally, there are three groups of roles that children enact in their fantasy play, depending on the choice of the children. The three common roles are (Hughes, 2010):

- **Family roles.** Most children are familiar with family roles. The youngest preschool children normally limit themselves to the family roles of mother, father, brother, sister and baby, while older children extend their roles to grandparents and other relatives.

- **Character roles.** The character roles are normally based on fiction or stereotypes. Stereotyped character roles are defined by personal characteristics or occupation, while fictional character roles are based on specific or various media such as from books, movies or TV programmes.

- **Functional roles.** The functional roles normally define the specific behaviour or plan of action such as aeroplane passenger, firefighter or monster. However, family and character roles can become functional roles. For example, a mother protects her child by hunting a monster or pirates prepare for an attack from enemies.

During preschool years, children are more likely to engage both in realistic or familiar roles (e.g. family members, doctor, postman, police officer) and unrealistic (e.g. cowboys, pirates, space creatures) fantasy play. The degree of fantasy in children's play is also influenced by the amount of their exposure to books, TV or movies (Hughes, 2010).

2.5.3 Props for Fantasy Play

The props are the materials that are used in most situations of children’s constructive fantasy play, to stimulate and support their imagination and to help and motivate them to be creative. For example, a child playing out a house scene may be equipped with a toy sofa or only a few wooden blocks transformed into a coffee table or chairs.

According to the developmental phase of a child, different types of props or materials can produce different types of fantasy play, but young children are more attracted to
physical objects, which can be touched and manipulated (McLoyd 1983). The occurrence of fantasy play and its complexity vary from one child to another, according to their level of maturity and to the objects available for playing (Fein, 1981; Harris & Butterworth, 2002; Moyles, 2005). McLoyd (1983) differentiates objects based on their degree of structure:

- **High-level structure / realistic object.** A high-level structured object is a representation of objects in the real world, whose meanings are known to children (e.g. dolls, dressing-up clothes, toy cars, and toy dining sets).

- **Low-level structure / non-realistic object.** A low-level structured object is a less direct association with the real word and children have more difficulty understanding the meaning (e.g. plastic shapes, blocks, cardboards, paper bags, boxes and sand).

During preschool years, play materials reflect increasing social maturity as children gradually become interested in adult roles and the expansion of their imagination. They appreciate miniature toys rather than adult models such as doll's houses, dolls, toy cars, spaceships and so forth (Hughes, 2010). However, gender differences in play gradually change during the preschool period; boys and girls start showing their preferences for what are considered to be gender-appropriate toys and activities (Harris & Butterworth, 2002; Moyles, 2005). Boys prefer to play with masculine toys such as vehicles, machines, weapons and sports equipment, while girls prefer to play with feminine toys such as dolls, doll’s houses and household items (Caldera, Huston & O'Brien, 1989). Selection of different toys based on gender in play helps children to understand and interpret more about their gender identity (Harris & Butterworth, 2002).

### 2.5.4 Solitary and Social Fantasy Play

Fantasy play can be solitary when a child shares a personal fantasy with other miniature toys, dolls or imaginary companions. However, the social fantasy play increases when a child starts to engage in play activity with other children. Fantasy play can help children grow socially and allows them to safely act out different roles and strong feelings in acceptable ways (Keenan & Evans, 2009). Haight and Miller (1993) in their longitudinal study with children (from when they were 12 months until they were 48 months) found that 75% of the fantasy play was social and only a minority of the play they observed was solitary. Children acquire new skills and learn to collaborate with others through social interaction and imitating each other (Africano,
Berg, Lindbergh, Lundholm, Nilbrink & Persson, 2004). According to one study, children tend to perform and develop more complex skills in play with friends than without friends (Werebe & Baundonniere, 1991). Evidence also revealed that shared make-believe or fantasy play occurs more often among friends than without friends, because friends' experiences with one another allow them to trust and believe that their partner will cooperate, interpret and share their meaning of symbolic play (Howes, 1996). Furthermore, play with friends encourages them to solve conflict in equal outcomes (less tendency of winning or losing) than without friends, and leads them to continue their play interactions and maintain positive relationships with one another (Deloache, Eisenberg & Siegler, 2006).

The role of adults and siblings in encouraging fantasy play has been investigated in many studies. For instance, Nielsen and Christie (2008) in their research with children from 27 to 41 months found that children's fantasy play increased immediately after adults modelled the fantasy play (using a doll's house and props). Dunn (2004) argued that older siblings might influence and contribute to a child's fantasy play experience. In her observations with second-born children, mothers would be involved in the fantasy play by making comments or suggestions; however, older siblings normally became involved and played with their younger siblings with verbal or non-verbal actions.

2.5.5 Imaginary Companions

Imaginary companions, or imaginary friends, are fantasy or pretend characters often invented by children between the ages of 2 and 6. Many children develop their imaginary companion from toys or props such as dolls, where they talk and engage with them in their fantasy play activities. The role of the imaginary companion to the child is normally as a friend or playmate. Most imaginary companions are usually human, have a name and are about the same age as the child, but the age can differ. The imaginary companion is quite often an animal such as a duck, a cat or a pony. Many researchers have found that an imaginary companion is important with several benefits; the pleasant companion is willing to listen and never gets impatient or bored (Taylor, Cartwright & Carlson, 1993). However, not all children have imaginary companions. The imaginary friends are likely to disappear as a child gets older.
2.6 Computers and Children

Children in modern society are growing up in a technological era in which computers have become a normal part of their daily lives. Adults and children often refer to children’s interaction with the computer as “playing with the computer” (Plowman & Stephan, 2005). Children are attracted to computer technology and want to “play” with it (Wyeth, 2006; Ovaska, Hietala & Kangassalo, 2003). Some critics claim that computers are replacing traditional ways of learning. However, Druin believed that, “interactive learning such as in multimedia did not replace the traditional learning but simply enhanced and supported experiences and offered children another way of learning” (Druin & Solomon, 1996). Computers offer unique opportunities for learning through exploration, creative problem solving, self-guided instruction; they come with advanced features such as interactive images and responses, and are therefore capable of attracting and maintaining the attention of young children. They can also support the development of young children, improving visual and verbal literacy and encouraging independence in constructing their own ways of exploring and gaining knowledge (Fails, Druin, Guha, Chipman, Simms & Churaman, 2005; Gibbs & Robert, 2003; Segers, 2003). Children like being in control and handle the computer with little interference from adults as a challenge to themselves to discover the world surrounding them (Africano, Berg, Lindberg, Lundholm, Nilbrink & Persson, 2004; Druin & Solomon, 1996). Observation at nurseries has indicated that while using computers children interact with others, negotiating access to the computer by taking turns, deciding where to click, and sharing the enjoyment of the action (Plowman & Stephan, 2005).

2.6.1 Designing for Children

Since the needs, skills and expectations of children are different from those of adults and older children, designers of children’s technology face distinctive challenges and many of the design principles used for adults cannot be applied to children’s products (Chiasson & Gutwin, 2005). Therefore, understanding the specific requirements of children as a special user group is instrumental in designing good, successful software for them to play with (Bruckman & Bandlow, 2002). When designing applications or software for children, there are two major areas that developers and designers should focus on (Markopoulos & Bekker, 2003):
• **Focusing on a specific age group.** Children of different ages have different preferences, interests and levels of skills. For instance, young children may face difficulties while interacting with computers due to their motor skill limitations; for example, pointing with a mouse to small objects could require more accuracy than they are capable of. Previous research has shown that young children aged 4-7 years need more time to aim and click accurately on small objects (Donker & Reitsma, 2006; Hourcade, Bederson, Druin & Guimbretiere, 2004). Use of the keyboard also needs to be avoided because too many buttons with different functions need to be remembered; children of this age are unfamiliar with letters and numbers, and the symbols on keyboard buttons do not clearly represent their functionality (Sluis, Weevers, Schijndel & Kolos-Mazuryk, 2004). According to Inkpen (2001), a mouse-controlled software specifically designed for children is more effective and children perform better at point-and-click rather than drag-and-drop interaction. Usability is very important when designing for children. Poor usability, combined with lack of patience when dealing with complex situations, induces children to leave the application. Usability is a prerequisite for learning and fun (Bruckman & Bandlow, 2002).

**Involving children in the design process.** In the traditional user-centred design process, user contributions are typically involved towards the end of the development lifecycle. However, working closely with users from the beginning of the development lifecycle could promote active user involvement, leading to good design results (Gould & Lewis, 1985). Scaife, Rogers, Aldrich & Davies (1997) have developed a framework, called ‘informant design’ that includes children in different stages of design. This approach values the use of a diversity of informants (e.g. children and teachers) to work together with the design team in maximising the contributions of inputs and suggestions in various stages of the design process. In this model, children contribute their input by explaining the difficulties or problems they found at the beginning of the process whereby the designer talks to the children with the existing materials. In the middle, children test out and provide ideas or perception on building interfaces through scenarios or games. At the end, the children evaluate interactivity and iterating designs through the task given in real-world contexts.
In 2002, Druin introduced the onion model, which showed the relation of various roles of children during the design process (Figure 3).

![Figure 3: Druin’s ‘Onion’ model. The relation of children’s roles to design activity during development of technology](image_url)

The four different ways in which children can be involved are as follows:

- **User.** The traditional role of children as end-users of technology is represented by the inner circle, with no involvement in design activity.

- **Tester.** The role of children changes in two ways in the outer circle as the children are also involved in testing during the design process.

- **Informant.** Children as informants contribute input during the design activity.

- **Designer.** The role of children as members of the design team means high involvement during the design activity.

The benefit of children’s contributions in the early stages of the development process is supported by several studies (Kelly, Mazzone, Horton & Read, 2006; Guha, Druin, Chipman, Fails, Simms & Farber, 2005).
In assessing the quality and usability of computer applications for children, the researcher focuses on the appropriateness of the development. The aim of the developer is mainly to make the software accessible, playful and more attractive for children to use without eliminating room for children’s imagination and creativity.

2.6.2 Evaluating Children’s Work and Play

There are several useful approaches for developers and designers in evaluating user testing with children (Markopoulos, Read, MacFarlene & Hoysniemi, 2008). These includes:

- **Observation.** The traditional design methods mainly use this approach, which focuses on children’s activities when they working or interacting with a product over a certain period of time. The researcher is able to collect in-depth information about a particular behaviour which can support design improvements or conclusion to the evaluation. From observation, the evaluator can identify what children do and what they say, provide fresh insights into children's play interaction and establish a wider perspective of the design technology (Wyeth, 2006). This also provides the children with more flexibility to explore and perform the given tasks, with less interruption to their activities. Observation can be done live during the evaluation session or afterwards by viewing video footage. However, the evaluator needs to focus on what to observe in order to keep within time and resource constraints. Therefore, it is important to decide beforehand which behaviours or events need to be observed and written up in the observation guide documents.

- **Recording and Logging.** Children’s behaviour during the evaluation session can be captured by several methods including written records (e.g. notes, tests, surveys); audio recordings (e.g. digital voice recorder, tape or CD of interviews); visual records (e.g. video footage, drawings, paintings, photographs) and automated logging (e.g. log-file). The recording and logging activity should not interfere with the activities of the children while interacting with the product. Video and audio are usually used to capture children’s facial expressions or behaviours. Normally, it is possible to have a portable setup of video recorder with built-in microphones in the study location. It is also very useful to use a tripod for the video recorder and set the location of the video recording safely out of children’s reach. In order to record facial expressions,
the room must be reasonably well lit. Automated logging involves the children’s inputs to the system without disturbing their evaluation tasks so that the evaluator can evaluate or analyse the data later. Children’s interaction movements are recorded in a log-file to make the analysis easier (Rick, Harris, Marshall, Fleck, Yuill & Rogers, 2009) and the screen output or the activity on the screen can also be captured as a video by software such as the Camtasia Studio Recorder. Commercial software is available to help with logging user inputs, screen outputs, assist the analysis and presents the results of the analysis, such as the Noldus Observer XT (refer to http://www.noldus.com/human-behavior-research/products/the-observer-xt) and Morae (refer to http://www.techsmith.com/morae.asp).

- **Verbalisation.** The verbalisation approach, normally referred to as ‘Think-Aloud’, is one of the main techniques to gather verbal reports as data for discovering problems in design (Ericsson & Simon, 1984; Nielsen, 1993; Nielsen 1994). This technique requires the children to verbalise their thoughts concurrently with performing given tasks during the evaluation session. In this technique, the evaluator needs to remain silent and should interfere as little as possible. However, encouragement or reminders can be given in order to persuade the participants to keep on thinking aloud. Boren and Ramey (2000) highlighted the difficulties of young children in verbalising their thoughts: children feel unnatural to share their thought to no-one without a partner. Besides, children may find difficult sharing their thoughts due lack of language development, being shy toward adults, the extra workload of the given evaluation task, and difficulty in commenting when trying to explore an unfamiliar product. Furthermore, children forget to think aloud and the evaluator needs to remind them frequently. Unfortunately, interruption may result in the children pointing out non-problem issues in order to satisfy the evaluator; they feel more comfortable if the evaluator just provides the instruction to think aloud, with less involvement during the evaluation (Donker & Reitsma, 2004). There are several variations of thinking aloud which make prompting unnecessary. For instance, in peer-tutoring (Hoysniemi, Hamalainen & Turkki, 2003) one child teaches another child how to use the product; and in construction interaction (Nielsen, 1993) children collaborate with each other in carrying out the given tasks. Hoysniemi, Hamalainen & Turkki (2003) found that the results and experiences of peer-tutoring are promising and it has proved to
be effective in detecting usability problems and in improving the design of a
game. Nielsen (1993) believed that construction interaction would be
appropriate for testing children, although young children may not really
cooperate (van Kesteren, Bekker, Vermeeren & Lloyd, 2003; Mazzone, Xu &
Read, 2007).

- **Survey.** The survey method of obtaining information by question and answer
includes questionnaires, structured interviews and rating scales. In general,
questionnaires are used for large groups of children and interviews are
normally conducted with one respondent at a time. Through a survey, the
evaluator may gather some information on children’s opinions about the
product or the evaluation tasks, and also ask children to contribute their own
suggestions for future research. Asking children questions after the test session
may help the evaluator to get feedback on what they think about the evaluation.
However, sometimes children are tired and not interested in answering
questions, so they should be kept to a minimum and be short, easy and simple
(Barendregt). Fun toolkit is an example of a survey method for gathering
opinions from children; it comprises four special tools (Read, Macfarlane &
Casey, 2006):

- **Funometer** was introduced by Risden, Hanna & Kanerva (1997). This tool
represents the amount of fun on the vertical scale. Two funometers are
illustrated in Figure 4, one that has been completed and the other waiting
for completion.

![Funometer](image)

- **Smileyometer** is based on the Likert scale and uses graphic signs; the
children tick one face to represent their opinion of the evaluation (Figure 5).
For example, a big smile represents delight and a face with a straight
mouth represents neutral.
• *Fun Sorter* is used to encourage children to rank a series of connected activities in order to evaluate which activity may be least fun (Figure 6). They are required to write the activity code in the spaces; the picture card can be used for younger children.

![Figure 5: Smileyometer](image)

• *Again-again Table* is used to get children’s feedback about the activity by ticking the activity that they want to play again (Figure 7). The list of activities is displayed on the left side with three columns spaces for Yes, Maybe and No.

![Figure 6: Fun sorter](image)

- *Wizard of Oz*. This approach is when the children interact with a functional or partially functional product during the evaluation session which is operated and controlled by an unseen human wizard. For instance, the children may think that they are interacting with the interface of the computer application, but in fact the evaluator sends the response or feedback of the application without their knowledge (Bekker, Hoven, Peters & Hemmink, 2007). This method is
useful if the cost of producing the product is high, as certain functions of the product can be evaluated before the final version is available. Based on a study with children aged 7-9, Hoysniemi, Hamalainen & Turkki, (2004) found that Wizard of Oz tests are easy to arrange as field tests and the information gathered from the them is very useful in the implementation and evaluation iteration. Hoysniemi & Read (2005) believed that this method facilitates large amounts of data gathering; non-experts can take part easily in the design process, as the design is not based on technological design and implementation. However, this method may lead to over-optimistic views on the development of the technology, and the approach may lead to unethical research where participants may lose respect for the research and unwilling to participate in future research (Hoysniemi & Read, 2005).

2.6.2.1 Testing with Children

Testing with children gives understanding of different ideas or perspectives of children about the product during the development stages. Hana, Risden & Alexander (1997) have developed a set of guidelines for testing with children, which the author think that the guidelines are suitable and appropriate for this study. This is due to this approach provides a comprehensive guidelines including before, during and testing session. Furthermore, this approach also emphasised on the safety awareness in handling task with children. The guidelines that proposed by Hana, Risden & Alaxander (1997) are as follows:

Before the test:

- The room should be made a little more child-friendly by adding a bit of colour and comfort and the display of decorations should be minimised as they may distract the child.
- Find out the regular input devices that the children use and set it them up before the test, as children may have difficulty switching from the input device they use at home to a different one in the test.
- Try to use the test equipment effectively. Make sure the microphone is placed close to the children to capture the children’s voices and smaller size of the microphone over large ones. The furniture setting should not directly face the video camera and one-way mirror as the children may interact with the camera or the one-way mirror rather than concentrating on the evaluation task.
Schedule a maximum of an hour evaluation session as preschoolers are generally only able to work for 30 minutes but may required extra time for play and exploration.

Establish a relationship with children by engaging them in a small talk and try to make them comfortable with the experimenter.

**During the test:**
- Preschoolers may require a little warm-up such as a simple game at the beginning of the test.
- The tasks should be divided into smaller segments, particularly complex activities. The experimenters also need to make sure the children understand the task given.
- Avoid asking children if they want to play with the task given. Try to use phrases such as “Now I need you to..” or “Let’s do this..”
- Gently remind the children to focus on the task if they start showing a loss of interest and try to motivate them to keep working on the task with comments such as “Let’s try some more..”

**Finishing up:**
- Evaluate how much children like the task by observing signs of engagements such as laughs and smiles or signs of disengagement such as sighs, yawns or walking away from the task materials.
- Reward the children by giving positive comments such as how helpful they were and provide a small gift as a token of appreciation.

### 2.6.3 Analysing Data

After the evaluation, data will be organised and coded with the aim of investigating useful information for suggesting and supporting the conclusion of the evaluation. The results of the evaluation can be analysed by two common methods:

- **Quantitative.** This method includes the number of instances of different groups of observations. It also involves a range of statistical techniques such as the descriptive and summary statistics (e.g. frequency of instances, percentages), inferential statistics and significance testing (e.g. cross tabulation, t-test, Wilxocon) and graphs and charts.
- Qualitative. This method includes the recorded behaviours of the participants during the evaluation, including thematic analysis (identification of themes based on the coding scheme), content analysis (systematic analysis focused on the actual content), narrative analysis (the evaluator listens to the stories of the participants) and grounded theory (developing the theory from the data).

During the process of data analysis, the findings of the study crucially depend on the focus of the analysis, which is normally based on the goal of the evaluation which the evaluator has planned to observe. Based on the focus of the observation, a simple observation guide or coding scheme should be developed by the evaluator, consisting of lists of the important variables, which later can guide the evaluator to code what they observe in order to ensure the data is analysed consistently (Markopoulos, Read, MacFarlane & Hoysniemi, 2008). It is a good practice to define the coding scheme clearly, whether it is for use in live observation or later when viewing the video footage. It is also easy to teach the coding scheme to others, especially when the evaluation involves more than one evaluator.

Jacobsen (1999) suggested adding more evaluators when analysing results, as more attention is needed to analyse rich and detailed data and also to ensure that results are valid and reliable. By including more evaluators, the workload of the data analysis can be split among evaluators and the task of coding can be done by working individually or in parallel. Good training and practice with the coding skills can ensure the data is coded correctly and reliably. However, there still will be a risk of possible different interpretations of the same information by different evaluators. The inter-coder reliability can be checked by comparing all the agreements and disagreements of the coding activity so that any inconsistency of the analysis can be discussed and resolved (Barendregt).

2.6.4 Fantasy Play and Technology

Most of the studies of fantasy play in the HCI literature explicitly focuses on story telling (Ryokai & Cassell, 1999; Cassell & Ryokai 2001; Ryokai, Vaucelle & Cassell, 2003).

- StoryMat (Ryokai & Cassell, 1999; Cassell & Ryokai, 2001), for instance, is an interactive imaginary playmate composed of a set of technology-augmented physical toys designed to support collaborative storytelling. The stories created playing with StoryMat were recorded and replayed by the system when other children created similar stories. From the evaluation with children aged 5 to 8,
StoryMat successfully performed as imaginary playmate and children who experienced stories from StoryMat enjoyed them as much as stories offered by real-life peers. StoryMat also offered children a play space where they could play naturally, physically involved, without the limitation of being tied down in front of the computer; to practice improving their imaginative and storytelling skills.

- **SAM** (Ryokai, Vaucelle & Cassell, 2003) is a 3D embodied conversational agent engaging children in collaborative storytelling using both physical and virtual objects. Sam (a virtual child aged 6) is presented as a peer playmate to the children and can construct, tell and listen to a real child’s stories with appropriate responses. Sam and the child can also pass physical toys across the actual and virtual worlds and construct stories collaboratively by taking turns. From the evaluations with children aged 5, Sam not only proved to be a capable playmate and storytelling partner, but was also a facilitator of peer interactions. Sam succeeded in communicating with children, encouraging them to use more linguistic expressions in storytelling and to engage in more collaborations in storytelling. User evaluation of all these devices demonstrated the value of technology in supporting explicit storytelling, but it offered little knowledge about children’s spontaneous fantasy play with virtual objects.

### 2.6.5 Tabletop Applications for Children

Interactive multi-touch tabletop is a new platform designed for multiple users to interact simultaneously with the digital environment. The use of tabletop technology or the interactive table as an input device has become popular in the market due to its capability as a direct-touch interface platform for shared-display groupware to support collaboration. This tabletop surface technology allows users to interact or view virtual materials with their peers in a large screen. According to Shneiderman (1991), touch screen technology is one of the easiest and most user-friendly of computer input devices. Much research has been done to support the view that it is easy to use, can support collaboration and offers more natural interaction styles (Apted, Kay, & Quigley, 2006; Dietz & Leigh, 2003; Piper, O'Brien, Morris, & Winograd, 2006). Based on these criteria, this technology might be suitable to accommodate and support non-expert computer users, especially young children, in interacting with the computer in an easy and natural way by touching the screen with their fingers; it will make interaction more interactive and enjoyable.
Several researchers have used tabletop technology to facilitate applications and support children in several areas:

- **Creativity/Imagination.** *StoryTable* (Cappelletti, Gelmini, Pianesi, Rossi & Zancanaro, 2004) is an application implemented on a DT tabletop requiring users to select information carried on virtual ladybirds, using their fingers to create a coherent story. From the evaluations, StoryTable helps children (aged 4-8) to be more involved and to increase their contribution to the story, through the attractiveness of the technology and innovative effects. *NIKVISION tabletop* (Marco, Cerezo, Baldasarri, Mazzone & Read, 2009; Marco, Baldassarri & Cerezo, 2010) is designed for nurseries and school children aged 3-6 years old. A set of farm animals (equipped with a fiducial icon underneath of each object) was exposed on the tabletop surface for children to play with. The toy objects on the tabletop were tracked and presented in a 3D virtual environment on the screen monitor. From observation, children were continuously looking at the monitor in order to find out the response to their actions and at the same time they needed to look at the object they wanted to play with on the table. *TellTable* (Cao, Lindley, Helmes & Sellen, 2010), is a new storytelling system designed to support children in creatively composing and sharing stories on an multi-touch interactive Microsoft Surface tabletop. The TellTable application allowed children to create characters and scenery based on drawing and the elements of the physical world (captured through photography). The story could then be recorded and replayed. From observation with children aged 7-13 years old, children enjoyed sharing their experiences of telling and watching stories with their peers and TellTable led some children to carefully plan their stories and decide their ideas in advanced.

- **Learning.** *DigiTile* (Rick, Rogers, Haig & Yuill, 2009) is an application implemented on a DT tabletop to support co-located collaboration. DigiTile is a construction kit for leaning about maths and art by designing colourful mosaic tiles. From the observations, children (aged 9-11) were able to work together and significantly improve their understanding of fractions. *OurSpace* (Harris, Rick, Bonnett, Yuill, Fleck, Marshall & Rogers, 2009; Rick, Harris, Marshall, Fleck, Yuill & Rogers, 2009) is a collaborative tabletop application to support the children to design a seating plan for their classroom. The intention of the study was to investigate the potential of using interactive tabletop technology to support children’s collaborative design task. This study also sought to
determine weather their participation was affected by their position at the tabletop. The design process started with sessions on a physical prototype using cardboard pieces and a paper of floor plan (Marshall, Fleck, Harris, Rick, Hornecker, Rogers, Yuill & Dalton, 2009). Children (7-9 years old) were invited to create a seating arrangement for their class using the virtual floor-plan of the classroom which was placed in the center of the tabletop so that all participants had good access to it. Children were observed completing the task in the multiple-touch condition and the single-touch condition. Findings showed that children in the multi-touch condition touched the tabletop surface 50% more than participants in the single touch condition. Another finding was that children touched all of the tabletop area but will worked mostly in the region of the tabletop nearest to their tabletop position. The Tangible and tabletop interface (Falcão & Price, 2009) is a study that focused on collaborative activity in a tangible tabletop environment to support learning about the physics of light. The aim of the study was to support students learning about the behaviour of light by exploring the concept of colour and light reflection. The interactive tabletop environment was based on reacTIVison technology and the application was developed in the processing language in order to support interaction between a set of concrete objects (different coloured plastic blocks and a torch tagged with fiducial icons). The camera underneath the table recognised and identified the object based on the fiducial icons which faced down and were in contact with the table surface. The interaction between the torch and the blocks triggered a visual effect projected on the tabletop surface, showing the reflection, transmission, absorption and refraction of light. From observation of 11-12 year-olds, all the children enjoyed interacting with the tabletop and creating a highly collaborative environment which led to productive knowledge exploration and construction.

- **Interaction. SIDES** (Piper, O'Brien, Morris, & Winograd, 2006) is a computer game that runs on tabletop technology, designed to help adolescents with Asperger’s Syndrome to practise effective groupwork skills using a four-player cooperative. The idea of SIDES is to support and motivate this kind of target population to work effectively in group situations, practise groupwork skills and decrease competition among group members. Findings from evaluations with middle school students (11-14 years old) revealed that cooperative tabletop computer games are a supportive and motivating tool for facilitating effective
groupwork among the target population. SIDES also revealed the potential of encouraging and building the target population’s confidence in their social abilities.

- **Reading.** Read-It (Sluis, Weevers, Schijndel, Kolos-Mazuryl, Fitrianie & Martens, 2004) is a multimodal, tangible and collaborative tabletop application that was designed to support young children’s (aged 5-7) reading skills in a novel way. Read-It allowed children to play a memory game whereby the system associated tangible bricks with a virtual memory card projected on the top of the physical bricks. The result from the evaluation demonstrated that children do benefit from the Read-It system in their reading learning. Read-It is easy to learn and offered children a space to learn in a collaborative and tangible environment. The uses of tangible bricks in the system helped children to improve interaction and encouraged them to apply different strategies during their learning process.

### 2.7 Conclusion

This chapter has presented readers with a better understanding of the background to preschool children and fantasy play. Previous work on the use of technology in children’s fantasy play and previous studies on tabletop technology related to the present research were also presented. The following are guidelines that were taken from the literature in designing the first study in this research:

**Consider the target user.** Preschoolers require extensive attention due to the fact they have different preferences, interests, requirements and levels of skill than older children and adults. Try to use devices that are easy for children to use because of their motor skill limitations (Hanna, Risden & Alexander, 1997). Try to ask the children to stand next to each other at the beginning of the task so they will have the same starting view of the research materials due to the difficulty of taking the viewpoint of others from their own perspective (Berk, 2009; Harris & Butterworth, 2002).

**Involve children in design process.** Invite children to contribute from the beginning of the development lifecycle to get a good product design and encourage active user involvement (Druin, 2002; Gould & Lewis, 1985; Scaife, Rogers, Aldrich & Davies, 1997).
Child friendly setting. Conduct the study at a location that can comfort the children and avoid a room with too many decorations as it may distract the children. Establish a relationship by introducing the experimenter to the children at the beginning of the session or engage them in small talk to avoid discomfort among the participants. A little warm-up at the beginning of the study may help the children to get familiar with the experimental task. The furniture arrangement should not directly face the video camera and one-way mirror as the children may interact with the camera or the one-way mirror rather than concentrating on the evaluation task (Hanna, Risden & Alexander, 1997).

Provide the props or materials to stimulate and support children’s play. Two different types of props or materials were proposed by McLoyd (1983): (1) High-level structure / realistic object which affords conventional usage whose meanings are known to children; (2) Low-level structure / non-realistic object which affords substitutions or to symbolise new meanings into objects.

Shorter tasks. Schedule a maximum of an hour experimental session due to the fact that young children are easily distracted and only pay attention to limited information for a certain period of time, but they may require extra time for play and exploration (Hanna, Risden & Alexander, 1997).

The details of the first study in this research will be described in Chapter 4. The following chapter will describe the approach taken in this research.
Chapter 3: Research Approach

This chapter describes the research approach used in this research. It begins with the ethical issues and explains how the data was collected and analysed.
3.1 Introduction

This chapter seeks to outline the approach by which this research was conducted. Working and conducting research with children is totally different from the typical practices conducted with adults. Therefore, it is necessary to determine an appropriate ethical approach in the experimental studies performed for this thesis. This chapter describes the general procedures for conducting the research, including a short questionnaires to parents, informal talk with the nursery teachers, observation of children’s play and a short interview with the children after the evaluation. Lastly, it describes how the data from the study was collected and analysed. The procedure will be explained in more detail in the empirical studies in chapters 4-6. This chapter is divided into four sections:

Section 3.2 provides principles for conducting ethical research with child participants.

Section 3.3 describes the step-by-step (before and during) evaluation procedures. This section describes the importance of understanding young children which involves observing and spending time with them, an explanation of how the tabletop was set up, a description of the study material development and the evaluation task design, and a description of the pilot study evaluation. This section also explains the play phase and training task procedure. Finally, the procedure of the interview with the children is given.

Section 3.4 describes how the analysis of the behavioural data analysis was performed.
3.2 Ethics in Research on Children

In order to perform the experiments in this research, many children were recruited as participants. In the UK, special ethical considerations are required in experiments which involve children, because they are considered to be more vulnerable than adults. Vulnerability means that parents, legal guardians or educators must be trusted to act to the best of their ability to make decisions on their behalf. Ethical approval was obtained for the entire research programme from the University of Manchester Research Ethics Committee before the experiments began. Overall, it took nearly a year to obtain this approval, which was officially granted in September 2007.

All researchers involved in the following studies underwent UK Criminal Record Bureau checks in order to be allowed to interact unsupervised with the children. They also strictly adhered to the regulations and procedures of the primary and nursery schools where the studies were conducted. The common principles for conducting ethical research with child participants are (Molich, Laurel, Snyder, Quesenbery & Wilson, 2001):

- **Safety and risk.** The researcher placed great emphasis on the importance of safety issues throughout the entire study. For instance, the procedure of the study was carefully planned, and the apparatus used in the study was properly set up in the study location agreed beforehand by the participating schools and nurseries. The detailed safety procedure for each study will be described in the experimental chapters (Chapters 4-6).

- **Consent.** Consent was required from the parents during the children’s recruitment at the school or the nursery. Detailed information about the study was distributed among the parents and children also received explanations about the general idea of the study. One parent or guardian was then asked to sign the consent form to confirm their child’s participation. Permission for photography, audio and video used in the study was also given by parents or guardians (refer to Appendix 13 and Appendix 14).

- **Withdrawal from the study.** The children and parents in the study were informed that they could withdraw from the study at any time. The children were reminded by the researcher about their right to withdraw whenever they were reluctant to continue their play before the end of the play session.
• **Privacy and confidentiality.** All data collected from the studies is confidential and all participants are anonymous. All children’s names were replaced with a code and only the codes are used in the presentation of the data.

### 3.3 The approach taken in this thesis

The studies that are presented in this thesis were conducted at the school or nursery because the children are already familiar and comfortable with the layout of the nursery or school building and it will be easier for the researcher to arrange the experimental sessions with the children. Furthermore, the children can be paired with their classmates based on their friendship to work with the task.

The approach as introduced by Scaife, Rogers, Aldrich & Davies (1997) for involving various participants (e.g. children and teachers) in the design process and Druin (2002) whereby the involvement of children as informant, tester and user during the research process were followed in this research (refer chapter 2). Rather than just observing the participants evaluate the prototypes, the children and teachers were invited to participate from the start in brainstorming and developing ideas. At the beginning of the design phase, the researcher conducted formal and informal interviews with the school or nursery teachers and a group of children. Then, the researcher turned their inputs into requirements of the application specification. In the design phase, prototypes were developed and tested with children and adults (three different high fidelity prototypes were used in Studies 1-3 and one low fidelity paper-based prototype in Study 3). A DT multi-touch interactive tabletop was used as the input device during the pilot testing. Any problems that occurred were resolved by redesigning the prototype; at the end of this phase, the final prototype of an interactive fantasy play in a tabletop environment for nursery children was produced and used for the evaluation phase. In the evaluation phase, empirical studies were conducted with a sample of nursery children. The DT multi-touch interactive tabletop was used as the input device. Children’s play behaviours were observed, recorded and analysed. Detailed procedures of the involvement of children in exploring and expanding the design space with their perceptions and values are described in each experimental chapter (refer to Chapters 4-6) and any problems or feedback from the task activity was noted as the new requirements for the new iteration cycle.
The iteration process in this research followed the task-artefact cycle shown in Figure 8: (1) Tasks; (2) Artefacts (Carroll, Singley & Rosson, 1991; Carroll & Rosson, 1992). The continuous iterative process in the task-artefact cycle, was a mutually dependent development between task and artefact. The task provides sets of requirements for the design of an artefact to help users perform the task. The output of the artefact generates new constraints or possibilities on task performance which often leads to recommend a modification of the original task. Then, the task sets new requirements for the redesign of the artefact.

![Figure 8: The iterative process](image)

### 3.4 General Design Procedure

This section provides the general procedure for designing the evaluation sessions for Study 1-3; including understanding the children, preparing the hardware, developing study materials, designing evaluation tasks and conducting the pilot study.

#### 3.4.1 Understanding the children

An understanding of their behaviour is important when conducting research with young children. This understanding helps to minimise poor design of the evaluation study, avoids errors in judgement and provides good results (Bruckman & Bandlow, 2002; Druin, 2002; Markopoulou, Read, MacFarlene & Hoysniemi, 2008). This research reviewed the literature on the theories of children and play development, and also the research evidence of how technology is used in children’s play (refer to Chapter 2). Another way to learn and understand more about children is to spend time with them (Druin, 2002; Niemi & Ovaska, 2007). Besides spending time with her own child, the
author had the opportunity to spend time with friends’ children, for example, going on outings and attending informal gatherings.

During the early stage of the research, observation sessions at the nursery were also conducted, whereby the researcher was able to study and understand the children’s activity and their play behaviour in a natural setting (Wyeth, 2006). The Criminal Record Bureau (CRB) documentation was required prior to the visits. During the observation sessions, the researcher had to minimise any disruption to the normal routine of the nursery and adhere to every request from nursery staff. The observations involved 15 children aged 3 and 4 years old from the Echoes Nursery, Manchester. The children were observed for 3 morning sessions during the indoor free-time activities. A total of 6 hours were spent observing children in the nursery. In general, the observation sessions gave the researcher the knowledge about the nature of children’s behaviour, such as the interpersonal relationships among children and play behaviours. The researcher also learned about the normal routine of the children at the nursery, before conducting the evaluation. The researcher also had formal and informal talks with the class teacher from the participating nursery before each part of the study, which was an opportunity to share and gain some information about the children (Druin, 1996; Druin, 1999).

3.4.2 Preparing the DiamondTouch multi-touch interactive tabletop setting

For the purposes of this study, the surface of the DT multi-touch interactive tabletop was located horizontally. For the special target users tested and for safety purposes, a robust iron frame was designed to mount the projector and to hold the DT tabletop. In Studies 1 and 2, a mirror was used to reflect the image from the projector to the tabletop surface. In Study 3, the image was projected directly on to the surface of the DT tabletop. A detailed explanation of the tabletop setting in each study will be described for the relevant experiment (refer to Chapters 4-6).

At the beginning of the DT tabletop usage, the projector was calibrated to allow users to directly manipulate interface elements projected on to the DT tabletop surface. The DTCalibrate application was used to match the DT coordinates with the position of the points of the screen coordinates, by prompting the user to touch a set of four points projected on to the DT tabletop surface (Figure 9). The input from the DT tabletop device was thus correlated with the positions of the graphics displayed on the projected screen. Refer to Appendix 17 for the DT tabletop manual configuration.
Chapter 3: Research Approach

3.4.3 Developing study materials

All study materials were prepared by the author. In Studies 1 and 3, both physical toys and virtual applications were used, but in Study 2 only a virtual application was used. All virtual application prototypes used in Studies 1-3 were designed and developed using Macromedia Flash. DTFlash framework was applied in developing and writing DiamondTouch multi-touch interactive tabletop applications. DTFlash consists of an API written in Flash ActionScript 2.0 that allows a DT application to be created in Flash. Details of the application prototype for each study will be described in the experiment chapters (refer to Chapters 4-6). Refer to Appendix 18 for instructions on how to develop the DTFlash application.

3.4.4 Designing evaluation tasks

The evaluation tasks for the study were based on the participants’ developmental stage and suitability (Hanna, Risden & Alexander, 1997; Niemi & Ovaska, 2007). The evaluation task is the assignment that the children were required to do during the evaluation session. Based on the characteristics of the target participants of this study, the approach of the evaluation task in this research was based on spontaneous and exploratory play whereby the children interacted with the study materials freely and without a predefined task. The general evaluation procedures for all studies will be described in the next section. Detailed procedures for each study will be described in the experimental chapters (refer to Chapters 4-6).

3.4.5 Conducting the pilot study

After the application prototype was developed for each experimental task, a pilot study was carried out with a small sample (children and adults), in order to gather information and to test whether the study task and materials were ready and could support the experiment. Detailed procedures of the pilot study conducted in each study will be described in each experimental chapter (refer to Chapters 4-6).
Chapter 3: Research Approach

3.5 General Evaluation Procedure

This section describes the general procedure for conducting evaluation sessions for Study 1-3 including before and during the evaluation session.

3.5.1 Before the Evaluation

Prior to the study, a formal request was made to the local head teacher of the school or the nursery near the university. After receiving approval from the participating school or nursery, the study location in the premises was identified and approved by the head teacher, based on the suitability and availability of the room.

Then, children from the nursery class were recruited for the purpose of the study. Every morning (for about a week) before the class session, the researcher personally distributed the study description together with the consent forms and a short questionnaire to all parents. During that period, parents were encouraged to ask questions or discuss with the researcher any issues or unclear information regarding the study. All participation was entirely voluntary. Parents of all the children who were interested in participating were invited to return the consent form and the questionnaire to the researcher or the nursery teacher before the given deadline; information included the child’s favourite activities (favourite stories, toys, TV shows and games), the child’s imaginary friend, the frequency, average time and the child’s purpose of using the computer. Refer to Appendix 15 and Appendix 16 for the details of the questionnaire and feedback for Studies 1-3.

Based on the list of respondents, the children were grouped in same-gender dyads by the class teacher, based on existing friendships to encourage collaborative play. The researcher also spent several hours in the nursery before the study, to build a relationship with the teachers and the children (Niemi & Ovaska, 2007).

3.5.2 During the Evaluation

The study apparatus and materials were set up in the morning at the study location, an hour prior to the first evaluation sessions. Two researchers were involved in each study. The main researcher interacted with the children, while the other person helped the researcher to handle the study equipment and video recording.
Each dyad was accompanied from their nursery class to the study location by the main researcher. At the beginning of the study, children were introduced to the assistant researcher. Then, the main researcher explained the safety procedures and other important information such as the emergency door and the location of the toilet. Each child was given a pair of coloured paper wristbands for easy recognition during video analysis.

Video cameras and screen capture were used to record all activities in the room and on the tabletop screen during the evaluation sessions. The video and the footage data removed the researcher’s need to remember or write down every action in detail so that she could concentrate fully on observing the play sessions (Goldman-Segall, 1996).

3.5.2.1 Play phase procedure
All dyads were invited and allowed to play with the study materials for approximately 10 minutes in each session. The evaluation time lasted not longer than 30 minutes to avoid participants becoming tired (Hanna, Risden & Alexander, 1997). The evaluation ended earlier if children explicitly requested it, or demonstrated any sign of being upset or bored, or if their concentration was diverted from the study materials for longer than two minutes.

At the end of each evaluation session, the main researcher asked the children about their experiences and preferences. Children were rewarded with a sticker as a token of appreciation before the main researcher accompanied the children back to their class.

3.5.2.2 Training task procedure (virtual setting)
In the virtual setting only, each dyad was invited to complete a simple training task as a warm-up session. At the beginning of the training task, the main researcher explained the basic rules on how to use the DT tabletop; these included the need for each child to keep their feet on the mat to sustain the connectivity to the tabletop, avoid bending their body forward on the table which could have distorted the image being projected on the tabletop screen, and avoid touching the table with both hands at the same time (the children were advised to put their non-dominant hands behind their backs). During the training task, seven little balls were displayed on the screen and each child was invited to drag them into a rectangular box. Each ball was associated with a different sound when it moved, such as ‘blip’, ‘dong’ and ‘ding’. When the ball was successfully
moved into a box, the sound of children cheering ‘hooray’ was produced. The training task was about 5 minutes, but the session ended earlier if children showed any sign of losing interest.

3.5.3 Interview procedure

A few days after the study, in order to obtain direct information from the children, a structured interview was conducted for about 10 minutes. The main researcher interviewed each child individually at the same study location. Children were accompanied by the main researcher from their nursery class to the interview location. The purpose of the interview was to collect more data to describe the sample of interests in terms of their fantasy play predisposition as children can vary significant on it. The interview followed the procedure proposed in Taylor and Carlson (1997). The children’s behaviours on a fantasy measure would be related to their performance on theory of mind tasks, whereby children who are more intelligent might engage in more fantasy. During the interview, children were questioned about their interest in fantasy and the development level of their fantasy play, including asking questions about their imaginary companions, likes preferences and impersonation games. Children were also asked to take a perspective-taking test (Theory of Mind Test). At the end of the interview session, children were awarded with a sticker as a token of appreciation.

3.5.3.1 Fantasy measures

- **Imaginary companion.** Children were asked the following questions to investigate their predisposition towards fantasy play. Initially, children were invited to say whether they had an imaginary friend. “Have you got a pretend friend?” If the child answered “yes”, the response score = 1; the “no”, response score = 0. Further questions about the imaginary friend were asked including its name, gender, age, whether it was embodied in a toy or completely pretend, where the friend lived and what the child liked and did not like about the friend.

- **Impersonation games.** Impersonation is a related activity considered to be intimately related to the formation of imaginary companions. Children were asked the following questions to find out about impersonation:

  (a) Have you ever played at being an animal? What animal do you like to be?
(b) Have you ever pretended to be a different person? What person did you pretend to be?

(c) Have you ever played at being anything else? What sort of thing do you like to be?

When the child answered "yes", their response score = 1; or "no", their response score = 0, for each impersonation question.

- **Imaginative play predisposition.** Children were asked the following questions to verify their likes and preferences and their preferences were classed as high or low fantasy oriented.

(a) Favourite story – Children were asked to name their favourite story. Their responses were coded as either fantasy oriented (e.g. “Snow White”) = 1, or reality oriented (e.g. animal stories) = 0.

(b) Favourite toy – Children were asked to name their favourite toy. Their responses were coded as either fantasy oriented (e.g. “Power Rangers”) = 1, or reality oriented (e.g. puzzle) = 0.

(c) Favourite TV show – Children were asked to name their favourite TV show. Their responses were coded as either fantasy oriented (e.g. “Lazy Town”, “Teletubbies”) = 1, or reality oriented (e.g. “Art Attack”, “Nina and the Neuron”) = 0.

(d) Favourite play (with other children) – Children were asked to name their favourite play when they were with friends. Their responses were coded as either fantasy oriented (e.g. playing house) = 1, or reality oriented (e.g. tag, play football) = 0.

3.5.3.2 Theory of Mind measure

The purpose of this test was to determine whether children’s behaviour in their fantasy play could be related to their performance on theory of mind tasks. In the test, the children took part in a short guessing game in which they were given a scenario based on false-belief and representational change tasks, and had to answer a set of questions (Figure 10).
Each child was given three different tasks. During the first task, each child was shown two characters (a puppet and a wooden doll), and introduced to the following scenario: The puppet named *Upsy Daisy* placed a toy car in the box (location A) and left the scene. The doll named *Hana* moved the toy car from the box (location A) to a bag (location B) in *Upsy Daisy’s* absence. When *Upsy Daisy* returned, the researcher asked the child “Can you tell me where *Upsy Daisy* thinks the toy car is?” In order to pass this task, the child must realise that *Upsy Daisy* will falsely believe that the toy car is in the box (location A), when in fact it is placed in the bag (location B).

For the second and third tasks, children were shown and asked to guess what was inside the containers (crayon box and eggs box). The researcher opened each box and the child discovered that it did not have the expected contents (e.g. plastic bottle in the crayon box and wooden doll in the eggs box). The object was placed back in the box and the researcher asked the child, “If Mrs. _____ (the class teacher) comes here and sees this box and she has not looked inside it, what will she think is in it? Does she think there are (crayons/eggs) or (plastic bottle/wooden doll) inside?” (the false belief question). Then, children were asked about their own earlier belief, “when you first saw this box, before we opened it, did you think there was (crayons/eggs) or (plastic bottle/wooden doll) inside?” (representational change question). Finally, children were asked again about the contents of the box to make sure they had not forgotten.

Besides the two surprising contents, children were shown and asked questions about two boxes that contained expected contents (e.g. a toothpaste box that contained...
toothpaste and a cereal box that contained cereal). By having two tasks with expected contents, children would not start to believe that all boxes had surprising contents. Their responses were coded as either correct, response score = 1; or wrong, response score = 0.

From the child’s responses, evidence of the variance of the child’s belief and reality would be provided. Children were also asked about their computer usage at home and nursery. At the end of the session, children were awarded with a sticker as a token of appreciation.

3.6 General Data Analysis Procedure

For the purpose of data analysis, all children’s names were replaced with a code. Only the codes were used in the presentations of the data.

3.6.1 Sample description analysis

Based on the responses to the questionnaire from the parents and the results from the child interview, a child was classified as having an imaginary companion if the child and the parent independently mentioned and described it. The child was classified as not having an imaginary companion if (a) the child responded by not having an imaginary companion; or (b) the parent mentioned their child’s imaginary companion but the child did not; or (c) the child mentioned his/her imaginary companion but could not give any details (e.g. a name for the imaginary companion). Furthermore, a child who mentioned impersonation character games was grouped as an impersonator character and a child without impersonation was grouped as not an impersonator character.

Then, children were divided into two groups (High and Low fantasy groups). The High fantasy group was selected based on (a) children who had an imaginary companion but not an impersonator character; (b) children who had not mentioned an imaginary companion but described their impersonator character; (c) children who had both imaginary companion and impersonation character. Children who had neither an imaginary companion nor impersonated a character were grouped in the Low fantasy group.

The individual differences in fantasy behaviour were assessed based on: (a) whether or not the child created an imaginary character; and (b) overall fantasy score from the
imaginative play predisposition interview. The child’s performance on the theory of mind development task was based on scores of all correct answers of the tasks. An independent evaluator double-checked all the analysis results and all differences were discussed and resolved.

3.6.2 Training phase analysis (virtual setting)

In the virtual setting, all footage of training sessions recorded by the Camtasia Studio Recorder software were used for analysis (Figure 11). All successful movements performed by each child during the training phase were marked and counted as 1 score when each ball was successfully dragged into the rectangle box.

![Figure 11: Camtasia Studio software](image)

3.6.3 Video data analysis

A major effort was devoted to define a methodology to analyse and interpret young children’s behaviour. This work evolved over the entire period of research with several iterations of analysis and interpretation. All videos of children’s play actions and behaviours were analysed. Adobe Premier Pro video editing software (Figure 12) was used to combine and synchronise two video footages of each session in one movie (side by side, or top and bottom).
The researcher then viewed each video several times in order to get a good understanding of the children's actions and speech. Written transcripts of all the videos were prepared by the main researcher viewing the video and transcribing concurrently. Each transcript was divided into 1-minute segments and comprised the children's verbal behaviour and gestures, with additional notations about circumstances that occurred during the session (e.g. prompts from the researcher, external noises). A transcript example is given in Table 1.
From the transcript, the variables of interest were defined following a combination of top-down and bottom-up thematic analysis and code development (Boyatzis, 1998). Thematic analysis is a general method in qualitative analysis, dealing with data that involves the creation and application of ‘codes’ to data. ‘Coding’ refers to the creation of categories in relation to data. Some variables, related to the main experimental variables, were defined based on theory (e.g. fantasy play events) and other variables (e.g. social behaviour, emotional expression, attention distribution, interaction with the tabletop, demonstrator involvement and other behaviour events) were derived from the observations and the analysis of the video. Atlas.ti qualitative analysis software was used as the tool of analysis whereby relevant children’s and demonstrator’s behaviour during the play sessions were identified and coded consistently (Figure 13).
3.6.3.1 Fantasy play analysis

The main analysis focused on the evidence of fantasy play during the play sessions. Pursuing a conservative approach, bouts of fantasy play were considered to occur only in the presence of explicit verbalisation or unambiguous vocalisation of a sound conventionally associated with an object, such as "vroom" for a car, or "splash" for water (McLoyd, 1983). This approach is recommended in developmental research as it distinguishes between genuine fantasy play and other forms of behaviour.

Video analysis was conducted based on event sampling, a method whereby the researcher captures all instances of a specified behaviour during a given time interval. The video was divided into intervals of one minute and for each of them it was scored if at least one instance of fantasy play occurred on a nominal variable present versus absent. The behaviour bouts were coded as one bout if any behaviour act occurred within the 1-minute time interval (Figure 14). Then, all bouts were further analysed following variables derived from the procedure proposed by McLoyd (1983):

- **Variety of themes.** The number of different story themes that were produced during play.
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- **Object substitution.** The number of times an object was converted into another entity (e.g. child pretends that a stick is a magic wand) or some of its features were altered (e.g. colour, size, gender).

- **Object onomatopoeia.** The number of various vocalisations of a sound linked with an object (e.g, “tringg” for magic wand, “ring” for telephone).

Any repetition of the same fantasy themes, substitution or object onomatopoeia produced in one particular time interval were scored only as one (e.g. a child repeatedly bouncing and mimicking “neighh” sound for the toy horse), or coded as an additional score if the child did something different with the toy horse (e.g. besides the child mimicking “neighh” sound for the toy horse, the child also mimicking “slurp” when the horse drinks from the pond). Furthermore, any actions that were clearly not fantasy were not coded as fantasy bouts.

3.6.3.2 Analysis of other observed behaviours

Other behaviours performed by the children during the play sessions were also noted. The coding scheme emerged from the data and was refined throughout the duration of the study, by adding events of interest as they were noted. Higher level categories were then created following an inductive approach grounded on data and combining similar actions. Video analysis of the children’s behaviours was coded based on similar content. Then, the collections of codes were grouped into categories based on similar concepts; see Figure 15.

![Figure 15: Schematic overview of formation process of other variables](image-url)
All the occurrences of each action were counted and for each of the variables analysed in the studies, three values were computed:

- **Dyads**, reporting the number of dyads which enacted the behaviour.
- **Frequency**, indicating the number of times a specific behaviour was noted.
- **Average rate**, indicating mean of frequency of the behaviour of each dyad over their playtime, measured in minutes. This variable rate allowed normalisation of data as play duration differed according to children’s choice and experimental settings. As such, rate was used for statistical comparison. The example of the average rate calculation as follows:

  **Example: Study 2 (Session 1) - Tap the table**

<table>
<thead>
<tr>
<th>Dyads</th>
<th>Play time</th>
<th>Convert time to numeric (x value)</th>
<th>Frequency</th>
<th>Frequency / X value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>00:08:50</td>
<td>8.83</td>
<td>8</td>
<td>0.91</td>
</tr>
<tr>
<td>Female 2</td>
<td>00:08:07</td>
<td>8.12</td>
<td>4</td>
<td>0.49</td>
</tr>
<tr>
<td>Female 3</td>
<td>00:08:29</td>
<td>8.48</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Male 1</td>
<td>00:05:05</td>
<td>5.08</td>
<td>2</td>
<td>0.39</td>
</tr>
<tr>
<td>Male 2</td>
<td>00:05:41</td>
<td>5.68</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>14</td>
<td><strong>14</strong></td>
<td><strong>1.79</strong></td>
</tr>
<tr>
<td>Mean (total/number of dyads)</td>
<td></td>
<td></td>
<td><strong>0.36</strong></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td><strong>0.38</strong></td>
<td></td>
</tr>
</tbody>
</table>

*E.g. time to numeric: 8 minutes 50 seconds = 8 minutes + (50 seconds/60 seconds = 0.83)=(8.83)*

Six macrocategories were extracted and defined in the following classes:

3.6.3.2.1 **Social behaviours**

All behaviours related to children’s interaction with each other were marked. From the video analysis, eighteen actions were highlighted and grouped into two major categories according to their valence: positive behaviour (reflecting collaboration) and negative behaviour (reflecting disruptive behaviour or conflicts). The list of the positive and negative social behaviours is as follows:

Positive behaviours:
- **Agreement.** The child agreed with his/her partner’s actions/verbal behaviour.
- **Ask for their turn.** The child asked for his/her turn to play.
- **Ask for object from partner.** The child asked for an object (play materials) from his/her partner.
- **Ask partner’s opinion.** The child asked for an opinion from his/her partner.
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- **Ask partner to move object.** The child asked his/her partner to move the object (study materials).
- **Copy partner.** The child copied his/her partner’s actions/behaviours.
- **Help partner.** The child reminded his/her partner to keep their feet properly on the mat or avoid putting two hands on the table.
- **Offer object to partner.** The child offered the object (study materials) to his/her partner.
- **Show object to partner.** The child showed the object (study materials) to his/her partner.
- **Suggest an action.** The child suggested his/her partner do an action.
- **Watch partner.** The child watched/observed his/her partner.

**Negative behaviours:**

- **Ask partner not to disturb.** The child asked his/her partner not to disturb.
- **Ask partner to stop.** The child asked his/her partner to stop playing with the study materials.
- **Disagreement.** The child disagreed with his/her partner’s actions/verbal behaviour.
- **End the play.** The child ended the play session.
- **Prevent partner get object.** The child prevented his/her partner from getting the object.
- **Refuse to play.** The child refused to play with the study materials.
- **Steal object from partner.** The child tried to get the object (study materials) from his/her partner.

### 3.6.3.2.2 Affective behaviours

All affective behaviours expressed by the children during the play sessions were observed and marked. Each of the behaviours made by a child was scored based on the start and end of each event. Twelve affective behaviours were identified and grouped into two major categories referring to positive and negative affective behaviours, which are as follows:

**Positive affective behaviours:**

- **Dance.** The child danced during the play session.
- **Excited.** The child looked excited, delighted or happy during the play session.
- **Jump.** The child jumped around during the play session.
- **Laugh.** The child laughed during the play session.
- **Sing.** The child sang during the play session.
- **Smile.** The child smiled during the play session.
- **Surprised.** The child looked positively surprised during the play session.
Negative affective behaviours:

- **Angry.** The child showed facial expressions and gestures indicating anger during the play session.
- **Bored.** The child showed signs of boredom during the play session.
- **Cry.** The child cried during the play session.
- **Frustrated.** The child showed facial expressions and gestures indicating frustration during the play session.
- **Sad.** The child showed facial expressions and gestures indicating sadness during the play session.

3.6.3.2.3 Attention distribution

The way children distributed their attention during the game was also analysed. All occurrences of distraction when children’s attention was detached from the main game were observed and marked. The distraction events were labelled when children were distracted and not paying attention to the study materials. The types of distraction observed from the play session are as follows:

- **Concentration.** The children’s attention was entirely devoted to one or more elements of the study materials. Rather than playing, the children appeared to put all their effort on manipulating the toys.
- **Look around.** The child looked around the room.
- **Look at demonstrator.** The child looked at the demonstrator.
- **Look at the mat.** The child looked at the mat and tried to keep his/her feet on the mat (only during the virtual setting).
- **Look at the projector.** The child looked at the projector during the play session (only during the virtual setting).
- **Look at demonstrator’s PC.** The child looked at the screen of the researcher’s PC (only during the virtual setting).
- **Noise distraction.** The child was distracted by external noise from the surroundings.
- **Play with hands and shadow.** The child played with his/her hands and the shadow reflected from the projector (only during the virtual setting).
- **Play with wristband.** The child played with his/her coloured paper wristband.
- **Walk away.** The child walked away from the study materials.
3.6.3.2.4 Interaction with the tabletop

The interactivity actions performed by the children while using the tabletop during the play session were identified and labelled. Eleven actions were noted and coded as follows:

- **Catch the avatar.** The child tapped the avatar (spider) using his/her finger(s) or hand.
- **Catch animated object.** The child tried to catch the animated object on the tabletop screen using his/her finger(s) or hand.
- **Children drag the same object.** Both children tried to drag/select the same object at the same time.
- **Drag two objects at the same time.** The child tried to drag/select two objects at the same time.
- **Drag the object around the screen.** The child dragged the object around the tabletop screen using his/her finger(s) or hand(s).
- **Hide object from screen.** The child hid the virtual object from the tabletop screen.
- **Sit on the table.** The child sat on the table.
- **Tap the tabletop.** The child tapped the tabletop using his/her finger(s) or hand.
- **Trigger animation in hot spots area.** The child triggered the animation by dragging the object into the hot spot areas (only in Study 2 and 3).
- **Trigger animation when objects overlapped.** The child triggered the animation by overlapping the object with another object (only in Study 3).
- **Try to change object in non-active area.** The child tried to change the object using the magic wand in the non-active area (only in Study 2).
- **Two hands on the table.** The child put two hands on the tabletop.
- **Wipe the tabletop.** The child wiped the tabletop screen using his/her finger(s) or hand.

3.6.3.2.5 Demonstrator involvement

Eight actions of the demonstrator involvement during the evaluation periods were observed and coded as follows:

- **Adjust participant’s feet.** The demonstrator adjusted the child’s feet in order to ensure the correct position on the mat (only during the virtual setting).
- **Adjust participant’s hand.** The demonstrator adjusted the child’s hand in order to ensure the correct position on the tabletop surface (only during the virtual setting).
- **Adjust participant’s mat.** The demonstrator adjusted the child’s mat in order to ensure it was in the correct position (only during the virtual setting).
- **Adjust tabletop.** The demonstrator adjusted the tabletop in order to ensure it was in the correct position (only during the virtual setting).
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- **Encourage participant.** The demonstrator encouraged the child to play with the study materials.
- **Remind participant.** The demonstrator reminded the children to keep their feet properly on the mat or to avoid putting two hands on the table (only during the virtual setting).
- **Remove participant’s hand.** The demonstrator removed one of child’s hands from the table to avoid interaction difficulties with the tabletop (only during the virtual setting).

3.6.3.2.6 Other behaviours

Two other actions or behaviours demonstrated by the children during the play session were observed and noted as follows:

- **Suck finger(s).** The child sucked his/her own finger(s).
- **Voice expression.** The child produced an unclear/random sound (not related to fantasy play).

3.6.3.3 Measuring the reliability of the data analysis

An independent evaluator double-checked the analysis completed by the researcher, by reviewing at least 10-20% randomly chosen video and transcript items (Tomasello, Striano & Rochat, 1999). Then, the reliability of the inter-coder was calculated based on the following metric (Markopoulos, Read, MacFarkane & Hoysniemi, 2008):

\[
\text{Percentage of reliability} = \frac{\text{Total of Agreements}}{\text{Total of Agreements} + \text{Disagreements}} \times 100
\]

Agreement refers to the event or observable behaviour coded identically by the researcher and the independent evaluator. Disagreement refers to the event or behaviour that has been given a different code or not coded at all. In the case of disagreement, all discrepancies were discussed and resolved (McLoyd, 1983). The reliability of the data analysis for each study will be described in the experimental chapters (refer to Chapters 4-6).

3.7 Conclusion

This chapter has described the methodology used and the ways in which the data of the three empirical studies was collected, analysed and organised. The approach used in this thesis can inform future study into conducting research with children, particularly preschool children. This is particularly important since little research has been
undertaken so far on preschool children. The next chapter will describe the details of procedures and report the results of empirical Study 1.
4 Chapter 4: Study 1: The Tree House (Physical vs. Virtual)

This chapter presents an exploratory study designed to compare fantasy play in a physical and a virtual environment. Twenty-two children (aged 3 and 4) in same-sex dyads were observed when they played with a real wooden tree house and with its virtual implementation on a Mitsubishi DT multi-touch interactive tabletop. The study highlighted several problems faced by children whilst interacting with the tabletop. The results of the study are presented and used to propose guidelines for improving the use of the DT multi-touch interactive tabletop by young children. Both quantitative and qualitative methods were used for data collection and analysis.
Chapter 4: Study 1 – The Tree House (Physical vs. Virtual)

4.1 Introduction

This chapter reports the first empirical study that was carried out in the research. The study aimed at exploring the degree to which spontaneous fantasy play can be elicited in 3 and 4 year-olds by real and virtual toys. The study was conducted to investigate and to improve our understanding of fantasy play in physical and virtual settings and to collect requirements for design. The study focused on the analysis of similarities and differences between types of play engaged in by children using real objects and virtual objects. This was an essential phase towards understanding the user requirements and tested the suitability of the tabletop environment for the target user group. At the time the study was planned, there was almost no empirical evidence to suggest that young children could interact with the interactive tabletop equipment. The study provided two settings for the children to play with. The first employed a wooden tree house with real objects and the second a virtual tree house implemented on the Mitsubishi DT multi-touch interactive tabletop device. Data was collected by observing children playing with both materials. Both qualitative and quantitative analyses were performed.

4.2 Method

4.2.1 Design of the Tree House

In this study, a tree house was designed and built in two different play environments by the author: the physical tree house and the virtual tree house. The physical tree house was designed using a combination of natural materials and the virtual tree house was implemented on a Mitsubishi DT multi-touch interactive tabletop. The idea of using the tree house in the study was based on the elaboration of Striano’s doll’s house in order to provide a gender-neutral play environment (Striano, Tomasello & Rochat, 2001).

The design of the tree house was based on a discussion with a group of four children aged 2½ - 6 years old and two teachers from the local nursery class. The first informal discussions were conducted with the children about their imagined tree houses. From the discussion sessions, all ideas from the children were gathered as guidelines for the development of the tree house. The suggestions of the tree house consisted of:

- Four levels of open-plan rooms attached to the trunk.
- The rooms were connected to each other by wooden stairs.
- A rope hung at one end of the room to connect to other room.
Then, the researcher conducted another informal discussion with the nursery teachers about the idea of the tree house. From the discussion, the teachers suggested using materials with textures (e.g. green sponge for the tree leaves, natural wooden sticks as the tree base) in designing the physical tree house as the preschool children were exposed and learned about textures at the nursery. Then, the researcher transformed all the ideas collected from the children and the teachers into the tree house.

4.2.1.1 Physical tree house

The trunk of the physical tree house was designed and made from a tall wooden block (62 cm height), which was covered with real twigs, and a rectangular wooden board (50cm L x 30cm W) was used as the base (Figure 16). Green sponges trimmed in shapes were used as leaves and grass. During the study, the tree house was placed on a coffee table (60cm L x 60cm W x 34cm H).

Following the experimental procedure proposed by McLoyd (1983) and Striano, Tomasello and Rochat (2001), a set of low-level structure and high-level structure
objects (refer to Chapter 2) was used and arranged on the table for children to play with, as shown in Figure 16.

- **Low-level structure objects** comprised two wooden sticks of different sizes, two small rocks and two sets of coloured wooden blocks of four different shapes (square, triangular, rectangular and cylinder).

- **High-level structure objects** were house-related miniatures consisting of five human wooden dolls (two females, two males and one baby) and a set of wooden props appropriate for the house setting (a toy car, a TV, a chair, a sofa, a lamp, a table and a vase). The set of objects used is illustrated in Figure 17.

![Figure 17: High-level structure and low-level structure objects (Study 1)](image)

4.2.1.2 Virtual tree house

A virtual model of the real tree house was designed and implemented in Macromedia Flash (Figure 18). The image of the virtual tree house was projected and displayed on the tabletop screen (76cm L x 60cm W). The 2D drawings of the tree house as well as the low- and high-level structure objects used were designed to look as similar as possible to the real tree house and the real objects. This included, in particular, the appearance of the tree house and the objects, such as the colours, shapes, dimensions and proportions. The user could drag and move the objects in the space with their fingers.
All objects were associated with a set of multimedia features and produced a different sound when moved, based on the type of object or shape. The set of objects is illustrated in Figure 19. The adult dolls said a word (‘hi’, ‘hello’), the baby doll made a sound (‘gaagaaguuguu’); a realistic sound was produced by the car (horn) and the lamp (‘click-click’) or a simple sound (‘dong’, ‘blip’, ‘boink’) for other objects. Several objects also performed some animations. For instance, the TV played a short video and music, the dolls waved and the light switched on every time it was moved. The stone and stick bounced around the screen when thrown and certain objects prompted animations when they overlapped. For instance, the female dolls performed a short dance in princess party dress and the male dolls waved in pirate party dress.

4.2.1.3 DiamondTouch Multi-Touch Interactive Tabletop

A robust metal frame was designed to hold the DT multi-touch interactive tabletop and mount the projector above the children’s maximum height (122cm from the table to the projector), making it unreachable by the children. A mirror was used to reflect the image from the projector to the tabletop surface. The frame was also used to attach the DT multi-touch interactive tabletop to the coffee table. The height of the coffee table was 45cm, which meant that children were able to reach all areas of the tabletop even
when there were seated. During the study, the children were invited to sit on two little stools. Two receiver mats were located underneath the stools so that the signal connection from the participant to the DT multi-touch interactive tabletop would not be lost if the children decided to stand up (Figure 20).

![Diagram of DiamondTouch multi-touch interactive tabletop setting](image)

**Figure 20: DiamondTouch multi-touch interactive tabletop setting (Study 1)**

### 4.2.2 Pilot study

Three series of pilot studies were conducted during the design of the experimental apparatus.

- **Pilot study 1 (DT multi-touch interactive tabletop).** The first pilot study was focused on the feasibility of the DT multi-touch interactive tabletop as the interaction device for the study. The idea of this pilot study was to test the setting of the DT tabletop so as to investigate the appropriate height for the projector and a suitable height for the frame that held the tabletop, in order to provide easy accessibility for young children to interact with the application. A sample of two children (accompanied by their parents) was invited to play with the tabletop in a laboratory of the Manchester Business School. The first session involved a female child (aged 2 years) and the second session involved a male child (aged 4 years). During the sessions, both children were invited to
play with the *veggie* interactive application (a sample DT application developed by Mitsubishi MERL) on the DT multi-touch interactive tabletop for about 5 minutes (Figure 21). During the session, the children were required to press the fire button on the screen in order to kill objects moving around the screen. Overall, the children expressed their excitement at playing with the DT tabletop as they enjoyed the large screen and the touch facilities.

![Figure 21: Veggie interactive tabletop application](image)

- **Pilot study 2 (physical tree house).** The second pilot study concentrated on the physical tree house. A total of six children (3 - 8 years old) were recruited to take part. All three sessions were conducted in the living room of the participant’s family or family friend’s house. The tree house (together with the high-structure and the low-structure objects) was arranged in the middle of the living room for children to play with. The first session involved two male children (aged 3 and 4), the second session involved two female children (aged 5) and the third session involved two female children (aged 7 and 8). All the children played with the physical tree house for about 10 minutes. In general, the pilot studies revealed that all the children enjoyed playing with the physical tree house (Figure 22).
Pilot study 3 (physical and virtual tree house). In the third pilot study, a sample of four children (aged 2½-5, accompanied by their parents) were invited to play with both the physical and the virtual tree house implemented on the DT multi-touch interactive tabletop in a usability laboratory of the Manchester Business School (Figure 23). The tree house (together with high-structure and low structure objects) was located in the middle of a small room and the DT multi-touch interactive tabletop was located in the corner of the other small room. The rooms were next to each other. The first session involved two male children (aged 5) and the second session a male child (aged 3) and a female child (aged 2½). All the children played with the physical and the virtual tree house for 10 minutes each. Overall, they all really enjoyed playing with the physical tree house. In the virtual setting, no major interaction problems were highlighted, as the children were capable of successfully moving objects on the tabletop. However, it was observed that when operating the tabletop, all the children concentrated very hard. They often tended to put both hands on the table and the experimenter frequently needed to remind them not to do so.
On the basis of these encouraging observations it was decided to go ahead with the experiment, as described below.

4.2.3 Participants

For the purposes of the study, 25 children (11 girls and 14 boys) were recruited from Webster Primary School in Manchester (UK); they were all attending the nursery on a full-day basis, five days a week. All children were between 3 or 4 years old (mean = 44 months, SD = 4.3 months). According to the report by Ofsted, the official UK body for inspecting schools (Webster Primary School Ofsted, 2007), this was an average-sized school, serving a neighbourhood with a high degree of social disadvantage. The majority of the children in the study came from minority ethnic backgrounds, as shown in Table 2 (and refer to Appendix 4).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mixed</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Asian or Asian British</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Black or Black British</td>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Chinese or Other Ethnic Group</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>No Answer</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>12</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>
Many of them did not speak English as their first language at home, but all of these children were able to communicate in English very well. Only six children were reported as the only child in the family, 18 children were reported to have siblings and only one child was of unknown status. Of the parents’ occupations, only 4% worked as professionals; 44% of the parents were students, 24% were housewives, 8% did casual work and 16% gave no response (refer to Appendix 5).

On the day of the study, one boy was absent and two children (one girl and one boy) refused to participate. Therefore, the study involved a total of 22 children (five dyads of girls and six dyads of boys). One of the girls was a special needs child.

### 4.2.4 Experimental Design

The study was based on a *within-subjects* design (setting: physical vs. virtual) and the order of playing was counterbalanced across dyads and gender. All the children played with both the physical and the virtual tree house for 10 minutes each. In the *physical* setting, children played with a wooden tree house and a set of real objects. In the *virtual* setting, a virtual tree house and virtual objects were displayed on the tabletop.

### 4.2.5 Procedure

#### 4.2.5.1 Evaluation phase

The study was conducted in a corner of a large hall during school time. The environment was often quite noisy as the room was also used by other teachers and students. However, several screens were set up for privacy. The general evaluation procedures were conducted as described in Chapter 3 (page 75). The physical and the virtual tree house were placed next to each other but only one could be seen at any one time, as shown in Figure 24 and Figure 25.
In the physical tree house setting, the dyad was invited by the researcher to play with the study materials. In the virtual tree house setting, each dyad was invited to complete a simple training task as a warm-up session before starting to play. During the training task, each child was invited to drag little balls into a rectangular box (Figure 26). The training task procedures were conducted as described in Chapter 3 (page 76).
The play sessions were recorded for analysis purposes. In the physical condition, there were two camcorders capturing the scene from two different viewpoints. In the virtual condition, one camcorder was used to record the children and the Camtasia Recorder software was used to capture the screen.

4.2.5.2 Interview phase

On the day of the sessions, one boy was absent. Therefore, the interview involved a total of 21 children (ten girls and eleven boys). The interview procedures were conducted as described in Chapter 3 (page 77). The interview setting is shown in Figure 27.
4.3 Data Analysis

The general data analysis procedure was conducted as described in Chapter 3 (page 80).

4.3.1 Sample description analysis

The sample description were analysed based on the procedures described in Chapter 3 (page 80).

4.3.2 Training phase analysis (virtual setting)

*Camtasia Recorder* software footage from a total of 11 training sessions was analysed, based on the general training phase analysis procedures described in Chapter 3 (page 81).

4.3.3 Play phase analysis

The general video analysis procedure was conducted as described in Chapter 3 (page 81). In the physical condition, a total of 22 video recordings were analysed. The play scene that was shot with two camcorders (zoom-in and zoom-out) at the same time was combined in one movie (side by side). In the virtual condition, 11 pieces of *Camtasia Recorder* footage and 11 video recordings were analysed.

4.3.3.1 Moving actions analysis

The first phase of analysis for this study concentrated on the *moving actions* where all objects moved from one position to another position by each child were noted. In order to support this analysis, A4 pictures of the two play environments were divided into rectangular areas in a grid pattern (Figure 28). Each area and object was labelled with a unique number for easy recognition and data analysis (Figure 28 and Figure 29).
Using the area grid-coding scheme, data was captured based on the type of object moved, first and final locations, the start and end time of each movement, and other important details. The total number of objects moved from their starting positions in the physical and the virtual tree house was also counted (*moved objects*). Actions were categorised in the following classes:

- **No-movement.** No movement, including all non-movement actions where children tried but failed to move the object from its original position.

- **Failed movement.** Failed movement, including actions where objects were moved but missed the target position (this could happen either because the children could not drag the object properly or because they did not raise their finger at the end of the movement).
Correct movement. Correct movement included all successful actions where children moved the object successfully to the target position.

An independent evaluator double-coded 11% of the videos. The inter-rater reliability was 97% and all discrepancies were discussed and resolved.

4.3.3.2 Fantasy play analysis

Children’s fantasy play was analysed, based on the fantasy play analysis procedures described in Chapter 3 (page 84). Some 70% of the analysis completed by the researcher was checked by another an independent evaluator. The inter-reliability was 92% and all discrepancies were discussed and resolved.

4.3.3.3 Other observational behaviours analysis

Children’s other behaviours were analysed, based on the other observational behaviour analysis procedures described in Chapter 3 (page 85). An independent evaluator checked 20% of the analysis completed by the researcher and the inter-reliability was 94%. Then, the researcher and the independent evaluator discussed and resolved the discrepancy. Refer Appendix 6 for basic quantitative data on behaviours.

4.4 Results

4.4.1 Sample description

Overall, only three out of twenty five children (two boys and one girl) met the criteria for having an imaginary companion. A total of thirteen other children mentioned that they had imaginary companions, but they did not meet the criteria because their parent did not report the child’s imaginary companion or provide any information in the questionnaires. A total of thirteen children (nine boys and four girls) were classified as an impersonator character and eight children (two boys and six girls) were classified as non-impersonator characters. In general, fifteen children were grouped as High fantasy (ten boys and five girls), six children were grouped as Low fantasy (one boy and five girls) and four children (three boys and one girl) was categorised in an unidentified group as they were absent during the interview and evaluation sessions.

A total of seven High fantasy group children scored more than 50% and eight children scored less than 50% in the imaginative play predisposition interview. Only one Low
fantasy child group scored more than 50% and 5 children scored less than 50% in the imaginative play predisposition interview.

Table 3 reports the mean numbers of correct responses on the theory of mind task by High and Low fantasy groups. There was no significant difference between the theory of mind scores among High and Low fantasy group, $t(19) = 1.6, p > 0.05$. These results support the findings of Taylor and Carlson (1997) on theory of mind scores among High and Low fantasy 3 year-olds, as the average age for participants in this study was under 4.

<table>
<thead>
<tr>
<th></th>
<th>High fantasy group (N=15)</th>
<th>Low fantasy group (N=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory of Mind scores</td>
<td>6.5</td>
<td>4.8</td>
</tr>
</tbody>
</table>

* N = number of children

### 4.4.2 Training phase (virtual setting)

The training phase lasted an average of 150 seconds (SD = 99 sec.) in which children only moved an average of two objects (little yellow and green balls). Six children failed to move any of them and strong individual differences were found, with only two children being capable of moving more than five balls. At the beginning of the training, children were very focused on the task; five children were too shy to play when they were observed by the researcher. A few minutes later, three children lost interest in the training game and after several unsuccessful attempts asked to play other games. Most of these unsuccessful attempts were due to them failing to move the object properly with their fingers.

### 4.4.3 Play phase

The average evaluation of the real tree house condition lasted 320 seconds (SD = 182 sec.) and the average of the virtual tree house lasted 300 seconds (SD = 170 sec.). As demonstrated by a Wilcoxon signed rank test, this time difference was not significant. Times in the two conditions were highly correlated ($r = .87, p < .001$) reflecting differences between dyads in levels of engagement with the study. The wide distribution of evaluation times in both conditions demonstrated strong individual differences, ranging from 69 to 600 seconds in the real tree house condition, and from 135 to 600 seconds in the virtual tree house condition.
4.4.3.1 General observations

All the children enjoyed playing with the physical tree house except for one boy who refused to join in. They engaged and became deeply involved with the physical toys whilst playing. However, the virtual tree house created problems. At the beginning of the play, children were not surprised by the technological setting, as if they were already used to it, but after a few minutes they started experiencing several interaction problems.

[Jo (girl, 3½ years) and Diana (girl, 3 years) play together with the virtual tree house]

(Diana watching Jo’s action)
Jo : (Drags the baby doll from the original place to the stair).
Jo : (Drags the toy car from the original place to the tree base). Ha ha.. (Laughing when the car produces the horn sound).
Diana : (Tries to drag the girl doll from the original place but is unsuccessful as the object does not stick to her finger. Looks at demonstrator and continues trying).
Jo : (Tries to drag the boy doll from the original to the tree house’s platform, but it slips from her finger and the object ends up at the tree base. Looks at demonstrator and continues dragging).

(Jo and Diana concentrate on dragging objects)

Very little evidence of verbalisation was recorded during the study, thus decreasing the possibility of revealing fantasy play. More frequent evidence of verbalisation was captured in the physical than in the virtual condition and high individual variations were identified in both environments. The example of silent play from a dyad during the evaluation sessions follows:

[Ben (boy, 3½ years) and Joe (boy, 3½ years) play together with the physical tree house]

Ben : (Picks up the sofa and puts it on the first platform attached to the tree. He picks up the girl doll and puts it on sofa)
Joe : (Picks up the baby doll and bounces it on the stairs as if the doll climbed the stairs to the next level and leaves it on the sofa next to the girl doll)
Ben : (Picks up the toy car and rolls it on the grass under the tree house)
4.4.3.2 Moving actions

The following results focus on movement actions performed by children during their play in both physical and virtual tree house conditions; for instance, every object movement made by a child from position x to position y, by interpreting the child’s intention based on the interaction context and their verbal comments.

In the physical condition unsuccessful action occurred when objects fell from the children’s hands while they tried to pick them up from the table (no movement) or when objects fell to the floor as the children tried to place them on the tree house (failed movements). Table 4 presents the frequency and percentage of moving actions for the physical and virtual conditions.

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virtual tree house</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No movement</td>
<td>514</td>
<td>58%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>72</td>
<td>8%</td>
</tr>
<tr>
<td>Correct movement</td>
<td>296</td>
<td>34%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>882</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Physical tree house</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No movement</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>22</td>
<td>4%</td>
</tr>
<tr>
<td>Correct movement</td>
<td>475</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>500</td>
<td>100%</td>
</tr>
</tbody>
</table>

Statistical analysis shows that the number of objects moved from their initial position was not significantly different between the two conditions (mean = 17, SD = 8.6 in the real tree house; mean = 14, SD = 6.4 in the virtual tree house). However, in the virtual environment, children tended moved objects randomly on the screen rather than moved to or within the tree house. An example of this behaviour is reported in the following transcript:

[Sara (girl, 4 years) and Kathy (girl, 3½ years) play together with the virtual tree house]

Sara:  (Drags the baby boy doll very slowly bit by bit)
   (She is concentrating hard) He is going …Look!
   (Smiles with satisfaction and continues dragging the baby boy very slowly)
Kathy:  (Tries to stop Sara)
   (She wants to drag the baby boy herself)
Sara:  (Will not let the baby boy go. Slowly she manages to drag the baby boy to the top of the tree house) He’s gone up!
   (Proud tone, smiles with satisfaction)
4.4.3.2.1 Interaction difficulties

In the virtual tree house condition, the degree of correct movement was very low (34%) even though the qualitative analysis indicated the performance of children improved with practice. The large distribution of correct movement, ranging from 12% to 75%, demonstrated strong individual differences and there was no correlation between object size and probability of success. The majority of unsuccessful actions in the virtual environment were due to no movements or failed movements. Several factors could have caused this, such as problems related to the application design, or to the tabletop interaction setting. In the physical tree house condition unsuccessful movements were rare.

A detailed analysis was conducted to investigate the interaction problems that occurred while children were working with the tabletop. From observation, most interaction problems were of the following types:

- The most common action discovered with the virtual tree house was that children tended to put both hands on the tabletop screen whilst interacting with the application, causing dragging object errors. This behaviour was observed 45 times, and the researcher constantly needed to remind them not to do so (N = 40). The requirement that the tabletop needed to be touched with only one part of the body at any time was clearly a challenging restriction for the children. As part of the solution to this problem, the researcher asked the children to put one hand behind their back while playing.

- Other issues were the tendencies of both children to try to drag the same object at the same time (N = 8), and a child who tried to drag two objects at the same time (N = 1), which also caused dragging errors. Children tapping the table (N = 20) was also observed in the virtual tree house condition as they tended to select the object by tapping on the object quickly (Table 5).
Table 5: The frequency, number of dyads involved and the average rate for interaction with tabletop (Study 1)

<table>
<thead>
<tr>
<th>Virtual tree house</th>
<th>No. of dyads</th>
<th>Frequency</th>
<th>Average rate (SD) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children drag the same object</td>
<td>2</td>
<td>8</td>
<td>0.10 (0.24)</td>
</tr>
<tr>
<td>Drag two objects on the same time</td>
<td>1</td>
<td>1</td>
<td>0.01 (0.03)</td>
</tr>
<tr>
<td>Tap the tabletop</td>
<td>6</td>
<td>20</td>
<td>0.39 (0.51)</td>
</tr>
<tr>
<td>Two hands on the table</td>
<td>9</td>
<td>45</td>
<td>0.82 (0.95)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>74</strong></td>
<td><strong>1.32 (0.89)</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

- Some of the children found it hard to drag and make the object stick to their finger, due to the small size of these objects. Different kinds of hand gestures performed by participants were observed. Most of the children experienced difficulties in pointing to and dragging the object with only one finger, as in Figure 30 (a). In some cases, the children tried to select and press the object but it hardly moved, which produced a squeaky sound from the table. They also tended to rest their forearm or other fingers on the tabletop surface to support their movement, as in Figure 30 (b).

![Figure 30](image)

**Figure 30:** (a) Recommended hand posture - point and drag; (b) Incorrect hand posture

Figure 31 (a) and (b) presents some unusual hand gestures performed by children while dragging the object. They frequently used their thumb or their middle finger in order to get better control in moving objects. In these cases, it appeared that they could move the objects more easily. In some minor cases, children demonstrated that they used their palm, all fingers, two fingers or even the little finger in order to drag the object.
Another typical problem was that children tended to move and rest their feet while sitting on the chair and did not place their feet on the mat in the required position (Figure 32). They often touched the mat only with their toes or with the corner of their feet so that the connection with the conductive mat was not sustained.

The researcher constantly needed to remind the children to keep their feet properly on the mat, even though they were perfectly aware that they had to do so as part of the task requirement.

Other interaction problems were that children had difficulty in reaching objects on the opposite of the table, and sometimes tried to climb on the table to get far away objects.

4.4.3.3 Fantasy play

A total of 24 bouts of fantasy play were observed in the physical tree house condition. These were produced by 5 out of 11 dyads. However, one dyad alone accounted for 10 bouts. In the virtual tree house condition, only 5 bouts of fantasy play were observed, produced by 2 of the 11 dyads, but one dyad alone accounted for 4 bouts.

Table 6 presents the frequency and the average number of Themes, Substitution, and Onomatopoeia contained in a fantasy play bout in the two experimental conditions.
results show a large occurrence of onomatopoeia when children played in the physical condition rather than in the virtual condition. More complex fantasy bouts enacted by the children in terms of story themes were observed in the physical condition, while no difference was found in terms of object substitutions.

| Table 6: The frequency and the mean for fantasy play characteristics (Study 1) |
|-------------------------------|----------|----------|----------|----------|
|                              | Themes   | Substitution | Onomatopoeia |
|                              | Freq | Mean | Freq | Mean | Freq | Mean |
| Physical tree house (N=24)   | 41   | 1.7  | 17   | 0.7   | 45   | 1.9   |
| Virtual tree house (N=5)     | 6    | 1.2  | 3    | 0.6   | 0    | 0.0   |

* N = number of fantasy bouts

From the general observations, children tended to enact their fantasy play themes around the provided props and most of the children loved to create stories relating to real persons (enacted by the dolls). Very few cases of object substitution were captured during the evaluation sessions. The following is an example from a dyad who played (in the physical condition), transforming the stone into a star, the dolls into fighters, and the sticks into swords.

[Jack (boy, 3½ years) and Tom (boy, 3½ years) play together with the physical tree house]

Jack : *Wiskkhh* (Moves the boy doll over Tom’s hand) *(fighting movement)* (He grabs the girl doll from platform 14, picks up the stone from the table and moves it to platform 14) *I’ve got star.* *(Proud tone)*

Tom : *(Picks up the stone and plays at platform 14)*

*I’ve got stone!.. I got the star!* *(Proud tone)* *(Tom and Jack enact fighting actions using the objects available at platform 14 – dollsticks, and stone - with vocalisations).*

Tom : *Bush,. bush.. I’m the stone adventure!*

Jack : *Blowww.. blowwww..* *(Continue playing in silence for a while) I got stone with the stick.*

Tom : *Dush!... dush!* *(They play together using sticks as swords. Tom picks the lamp from the table, puts it on platform 14 and shows it to Jake) Look.. what I’ve got.. dushhh!!*

*(Pushes the lamp from platform 14)*

Overall, a total of 17 bouts of fantasy were performed by the *High fantasy* group in the physical tree house condition. These were produced by 4 out of 15 high fantasy dyads, but with 1 dyad alone producing 8 bouts. A total of 5 bouts of fantasy were performed by the *Low fantasy* group which were produced by 2 out of 6 dyads, but 1 dyad alone accounted for 4 bouts. Another 2 bouts of fantasy were produced by a dyad who did not belong in either fantasy group due to being absent during the interview session. In the virtual tree house condition, only 2 fantasy bouts were performed by the *High*
fantasy group, produced by 2 dyads. 3 bouts were produced by the Low fantasy group, but 1 dyad alone accounted for all the bouts.

The frequency and the mean of the structure of play objects used per dyad in the study are shown in Table 7. In the virtual tree house condition, dyads significantly used more high structure objects than low structure objects, $t(20) = 2.3, p < 0.05$. However, in the physical tree house condition, there was no significant difference between use of high and low structure objects, $t(20) = 1.5, p > 0.05$.

Table 7: The frequency and the mean of High and Low structure objects used per dyad in two play sessions (Study 1)

<table>
<thead>
<tr>
<th>Object Structure</th>
<th>Physical tree house (N=11)</th>
<th>Virtual tree house (N=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
</tr>
<tr>
<td>High Structure Object</td>
<td>318</td>
<td>28.9</td>
</tr>
<tr>
<td>Low Structure Object</td>
<td>181</td>
<td>16.5</td>
</tr>
</tbody>
</table>

* N = number of dyads

Table 8 reports the mean per dyad of fantasy play components enacted with high and low structure objects. In the physical tree house condition, there was no significant difference between high and low structure objects in fantasy themes, $t(11) = 1.3, p > 0.05$; substitution, $t(20) = -0.12, p > 0.05$; or onomatopoeia, $t(20) = 0.87, p > 0.05$. However, in the virtual tree house condition, fantasy themes were only produced in the presence of high structure objects and no evidence was produced for low structure objects. Fantasy substitution produced by high and low structure objects was not significant, $t(20) = 0.447, p > 0.05$. There was no evidence of onomatopoeia produced by high or low structure objects.

Table 8: The frequency and the mean of fantasy play components expressed per dyad in play sessions with High and Low structure play objects (Study 1)

<table>
<thead>
<tr>
<th></th>
<th>Themes</th>
<th>Substitution</th>
<th>Onomatopoeia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Physical tree house (N=11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Structure Objects</td>
<td>33</td>
<td>3.0</td>
<td>5.7</td>
</tr>
<tr>
<td>Low Structure Objects</td>
<td>8</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Virtual tree house (N=11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Structure Objects</td>
<td>6</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Low Structure Objects</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* N = Number of dyads
Chapter 4: Study 1 – The Tree House (Physical vs. Virtual)

The few bouts of fantasy play recorded in the virtual condition occurred within this new game: the moving challenge. When the children were not capable of performing the movements themselves they did not hesitate to ask for help, as illustrated in the following transcript. This is an interesting example where the fantasy play is achieved by a conjoint effort: Sam is the author, Charlie the partial executor, and in case of difficulty the experimenter is called in to help.

[Sam (boy, 3½ years) and Charlie (boy, 3½ years) play together with the virtual tree house]

Sam : Can you do…. can you do that car?
   (Addresses Charlie while trying to drag the car)
Charlie : (Drags the TV) Aaahhh! (Smiles and has fun dancing to the TV music) Listen!
Sam : Can you do…. can you do that.. can you do that? (Points to the car and tries to
   drag it)
Charlie : (Tries to help Sam to drag the car)
Sam : This one. (Points at the blue square box) Put it there.. put it in the car.. put it in the
   car.. put it in the car!
Charlie : (Drags the red triangle to the car)
Sam : Can you.. Can you put my doll over there?
   (Addresses the experimenter while pointing at the boy)
Charlie : Put the doll there. (Points at the car)
Sam : He says hello!

4.4.3.4 Social behaviours

Table 9 reports the number of dyads involved, the frequency and the average of the frequency over play time for social behaviours. Overall, as demonstrated by a Wilcoxon signed rank test, there was no significant difference between average rate of positive and negative social behaviours in the physical (Z = -0.400, p > 0.05) and in the virtual condition (Z = -1.6, p > 0.05).

A Wilcoxon signed rank test revealed that there was no significant difference between the average rate of positive social behaviours in physical and virtual conditions (Z = -0.845, p > 0.05), and no difference between physical and virtual conditions in negative social behaviours (Z = -1.07, p > 0.05).

Observation of children asking their partner to move an object and watching their partner during the play sessions were recorded more frequently in the virtual condition than in the physical condition. The following is an example of a child who watched her partner during the physical and virtual condition play sessions.
Chapter 4: Study 1 – The Tree House (Physical vs. Virtual)

[Molly (girl, 3½ years) and Hana (girl, 3 years) play together with the physical tree house]

Molly: (Watching Hana’s actions)
Hana: Flowers.. hmmm… (Picks up the vase from the table and puts it on platform 14 but the vase falls down)
Molly: (Smiling and continuing to play. Picks object girl from the table and puts it on platform 6)

[Ken (boy, 3 years) and Scott (boy, 3½ years) play together with the virtual tree house]

Ken: (Watching Scott’s actions)
Scott: (Scott tries to drag the boy doll object but it does not stick to his finger. He looks at the demonstrator and continue move the object bit by bit).

However, there was more evidence of agreement and a child copying his or her partner in the physical than in the virtual condition. The following example displays a child who copied his partner during their play in the physical and virtual tree house conditions.

[Jack (boy, 3½ years) and Tom (boy, 3½ years) play together with the physical tree house]

Jack: (Picks boy doll A from the table and bounces on stairs to platform 6)
Tom: Look! I have same as you.. (Picks boy doll B from the table and bounces on stairs to platform 6)

[Timmy (boy, 3 years) and Eddie (boy, 3½ years) play together with the virtual tree house]

Timmy: (Drags the baby doll using his thumb)
Eddie: (Watching Timmy dragging the object. Later, he drags the boy doll with his thumb)

The results show that a larger occurrence of children prevented their partner from getting the object when they played in the physical condition than in the virtual condition; they loved to hold the physical toys in their hands. Children trying to steal an object from their partner were also observed more frequently in the virtual condition than in the physical condition. There was frequent evidence of children refusing to play in the virtual condition, and this mostly happened after several minutes of tabletop interaction difficulties.

However, several other social behaviours occurring only once were observed in the physical condition including requesting object from partner, offering object to partner, showing object to partner, and a child refusing to play. Only one occurrence each of asking partner to stop, ending the play and preventing partner getting the object was observed in the virtual condition.
### Table 9: The number of dyads involved, the frequency, and the average rate for social behaviours (Study 1)

<table>
<thead>
<tr>
<th></th>
<th>Physical tree house</th>
<th></th>
<th>Virtual tree house</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Average rate (SD) **</td>
<td>No. of dyads</td>
</tr>
<tr>
<td>Positive behaviours (7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agreement</td>
<td>11</td>
<td>123</td>
<td>0.34 (0.22)</td>
<td>10</td>
</tr>
<tr>
<td>Ask partner to move object</td>
<td>9</td>
<td>45</td>
<td>0.11 (0.11)</td>
<td>0</td>
</tr>
<tr>
<td>Ask for object from partner</td>
<td>1</td>
<td>1</td>
<td>0.01 (0.02)</td>
<td>1</td>
</tr>
<tr>
<td>Copy partner</td>
<td>8</td>
<td>20</td>
<td>0.001 (0.004)</td>
<td>0</td>
</tr>
<tr>
<td>Offer object to partner</td>
<td>1</td>
<td>1</td>
<td>0.002 (0.007)</td>
<td>0</td>
</tr>
<tr>
<td>Show object to partner</td>
<td>1</td>
<td>1</td>
<td>0.003 (0.01)</td>
<td>0</td>
</tr>
<tr>
<td>Watch partner</td>
<td>9</td>
<td>52</td>
<td>0.15 (0.12)</td>
<td>10</td>
</tr>
</tbody>
</table>

| Negative behaviours (6)              |             |     |                     |             |     |                     |
| Ask partner not to disturb           | 8          | 20  | 0.05 (0.06)         | 8          | 26  | 0.10 (0.12)         |
| Ask partner to stop                  | 1          | 2   | 0.01 (0.02)         | 0          | 0   | 0.00 (0.00)         |
| End the play                         | 2          | 2   | 0.00 (0.00)         | 1          | 1   | 0.01 (0.02)         |
| Prevent partner get object           | 3          | 9   | 0.02 (0.03)         | 1          | 1   | 0.004 (0.01)        |
| Refuse to play                       | 1          | 1   | 0.002 (0.005)       | 5          | 12  | 0.06 (0.11)         |
| Steal object from partner            | 4          | 6   | 0.01 (0.02)         | 3          | 11  | 0.03 (0.06)         |

** Average rate = (the mean of frequency of the behaviour of each dyad over their playtime in minutes) / number of behaviours for each category

### 4.4.3.5 Affective behaviours

Table 10 presents the number of dyads involved, the frequency and the average of the frequency over time for affective behaviours in the two conditions. In the physical condition, the enjoyment of children playing with the tree house was demonstrated by a significant difference between the average rate of positive and negative emotions ($Z = -1.960, p < 0.05$). High frequencies of smiling, excitement and laughing were observed during the play session.

Despite the difficulties of interaction with the tabletop, there was also evidence of positive emotions (N = 52) such as smiling, laughing, surprised and excitement in the virtual condition. However, a Wilcoxon test revealed that there was no difference between the average rate of positive affective behaviours and negative affective behaviours in the virtual condition ($Z = -1.580, p > 0.05$).

The high occurrence of frustration in the virtual condition was mainly due to the high level of errors in handling object movements on the tabletop. The evidence of a child jumping during the play session was observed once in the physical condition.
Table 10: The number of dyads involved, the frequency and the average rate for affective behaviours (Study 1)

<table>
<thead>
<tr>
<th></th>
<th>Physical tree house</th>
<th></th>
<th>Virtual tree house</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Average rate (SD)**</td>
<td>No. of dyads</td>
</tr>
<tr>
<td><strong>Positive behaviours (5)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excited</td>
<td>6</td>
<td>52</td>
<td>0.17 (0.22)</td>
<td>10</td>
</tr>
<tr>
<td>Jump</td>
<td>1</td>
<td>1</td>
<td>0.02 (0.06)</td>
<td>0</td>
</tr>
<tr>
<td>Laugh</td>
<td>2</td>
<td>9</td>
<td>0.03 (0.07)</td>
<td>3</td>
</tr>
<tr>
<td>Smile</td>
<td>6</td>
<td>30</td>
<td>0.11 (0.13)</td>
<td>9</td>
</tr>
<tr>
<td>Surprised</td>
<td>2</td>
<td>2</td>
<td>0.01 (0.01)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Negative behaviours (4)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angry</td>
<td>1</td>
<td>1</td>
<td>0.002 (0.01)</td>
<td>1</td>
</tr>
<tr>
<td>Bored</td>
<td>1</td>
<td>1</td>
<td>0.01 (0.03)</td>
<td>2</td>
</tr>
<tr>
<td>Frustrated</td>
<td>2</td>
<td>2</td>
<td>0.01 (0.02)</td>
<td>3</td>
</tr>
<tr>
<td>Sad</td>
<td>1</td>
<td>1</td>
<td>0.002 (0.008)</td>
<td>2</td>
</tr>
</tbody>
</table>

** Average rate = (the mean of frequency of the behaviour of each dyad over their playtime in minutes) / number of behaviours for each category

4.4.3.6 Attention distribution

The number of dyads involved, the frequency and the average of the frequency over time for attention distribution observed during the play are reported in Table 11. The most common type of attention distribution that occurred in the virtual condition was concentration, mainly due to the high occurrence of errors in handling object movements on the tabletop, which needed high concentration. Wilcoxon test revealed that the average rate of concentration behaviour was significantly more in virtual than physical conditions (Z = -2.667, p < 0.05).

During the play time, children tended to pause in their play, look around and continue their play after a while. More evidence of this was significantly higher in physical than in virtual conditions (Z = -2.401, p < 0.05) due to the high commitment to concentration when moving objects in the virtual condition. Children also tended to look at their mat in the virtual condition in order to ensure their feet were in the right position. High occurrence of children looking at the demonstrator was observed in both physical and virtual conditions. This may reflect the confidence level of young children playing with the study materials, or concern about being observed by the demonstrator. However, Wilcoxon revealed that there was no significant difference between the average rate in virtual and physical conditions (Z = -0.178, p > 0.05).
There were seven instances of children looked at the demonstrator’s PC in the virtual tree house, when they quickly stepped into the demonstrator’s area and checked the computer screen. The noisy environment apparently distracted the children while playing with the study materials. For example, participants turned round and looked behind them when they heard: (a) a noisy sound from the other side of the room; (b) someone walking near the study location; or (c) the school’s bell ringing. In the virtual condition, the noise affected concentration on moving objects on the tabletop surface. However, Wilcoxon showed no significant difference between the average rate in physical and virtual conditions ($Z = -1.481$, $p > 0.05$).

In the physical condition, children tended to walk away from the table; sometimes, they took along the physical toys and walked around with them in their hands. In the virtual condition, there was little evidence of children walking away from the study materials, maybe because they were sitting on stools whilst interacting with the tabletop. However, Wilcoxon revealed that there was significant difference between the average rate in physical and virtual conditions ($Z = -2.380$, $p < 0.05$).

Children tended to play with their wristband and were observed doing so in both conditions (six cases in each). However, on some occasions in the virtual condition, children tended to play with the coloured shadow reflected on their hands from the projector, which indirectly attracted them to play with the shadow.

Table 11: The number of dyads involved, the frequency and the average rate for attention distribution (Study 1)

<table>
<thead>
<tr>
<th></th>
<th>Physical tree house</th>
<th></th>
<th>Virtual tree house</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Frequency</td>
<td>Average rate (SD) *</td>
<td>No. of dyads</td>
</tr>
<tr>
<td>Concentration</td>
<td>2</td>
<td>3</td>
<td>0.17 (0.38)</td>
<td>11</td>
</tr>
<tr>
<td>Look around</td>
<td>11</td>
<td>68</td>
<td>1.79 (1.58)</td>
<td>10</td>
</tr>
<tr>
<td>Look at mat</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
<td>4</td>
</tr>
<tr>
<td>Look at demonstrator</td>
<td>11</td>
<td>77</td>
<td>1.73 (1.15)</td>
<td>11</td>
</tr>
<tr>
<td>Look demonstrator’s PC</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
<td>3</td>
</tr>
<tr>
<td>Noise distraction</td>
<td>4</td>
<td>12</td>
<td>0.17 (0.29)</td>
<td>9</td>
</tr>
<tr>
<td>Play with hands &amp; shadow</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
<td>1</td>
</tr>
<tr>
<td>Play with wristband</td>
<td>3</td>
<td>6</td>
<td>0.11 (0.20)</td>
<td>5</td>
</tr>
<tr>
<td>Walk away</td>
<td>8</td>
<td>32</td>
<td>0.68 (0.72)</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>198</strong></td>
<td><strong>4.66 (3.17)</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes
4.4.3.7 Demonstrator involvement

Table 12 reports the number of dyads involved, the frequency and the average of frequency over play time for demonstrator involvement in the two play sessions. Demonstrator and children interaction in the physical condition was relatively rare as the children had no problems using or playing with the physical tree house.

However, in the virtual condition the demonstrator had to monitor the children’s behaviour very closely due to the difficulties they had in moving the object on the screen. In general, the children rarely requested help verbally when they were stuck. On most occasions, the demonstrator preferred to encourage children to continue trying and only helped when they looked frustrated after several attempts. Wilcoxon showed that there was significant difference between the average rate of encourage participant in physical and virtual conditions (Z = -2.756, p < 0.05).

Certain conditions did require quick actions from the demonstrator, such as adjusting feet on the mat, adjusting or removing hands on the table, and adjusting the mat or the table setting in order to avoid errors whilst interacting with the tabletop.

<table>
<thead>
<tr>
<th></th>
<th>Physical tree house</th>
<th>Virtual tree house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust participant’s feet</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Adjust participant’s hand</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Adjust participant’s mat</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Adjust tabletop</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Encourage participant</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Remind participant</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Remove participant’s hand(s)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>11</td>
</tr>
</tbody>
</table>

*Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes*
4.4.3.8 Other behaviours

Other behaviours were observed and the number of dyads involved, the frequency and average of the frequency over play time is reported in Table 13. There was evidence of children sucking their fingers in both play sessions. However, in the virtual condition, sucking fingers whilst interacting with the tabletop caused slipping when dragging the object because of the wet fingers. Unexpected voices or sounds expressed by the children, unrelated to the fantasy play, were also captured during both play sessions (e.g. ‘aauuwww’, ‘oooooo’). Wilcoxon test revealed no difference between the average rate of voice expression in physical and virtual conditions ($Z = 0.0, p > 0.05$).

<table>
<thead>
<tr>
<th></th>
<th>Physical tree house</th>
<th>Virtual tree house</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Frequency</td>
</tr>
<tr>
<td>Suck finger(s)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Voice expression</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

4.4.3.9 Preferences

At the end of the evaluation, children were asked to name their favourite play environment and the results are shown in Table 14. Surprisingly, the feedback from the children was very positive. Even the unfamiliar hardware setting (i.e. DT table and projector connected to the metal frame), uncommon interaction requirements (i.e. the need to remain connected to the mat) and poor interaction experienced with the tabletop (e.g. difficulty in dragging the object) did not stop the children from preferring the virtual or tabletop environment to the physical environment. Only 3 children did not have any play environment preferences. The participants were not influenced in any way by the researcher in making a specific decision.

<table>
<thead>
<tr>
<th></th>
<th>Physical mode</th>
<th>Virtual mode</th>
<th>No Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children preferences</td>
<td>5</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>
4.4.4 Interview phase

During the interview session, some of the children were quite shy at the start. However, they were more comfortable as the session progressed. In some cases, children were distracted by the noisy environment and the researcher had to ask them to focus on the interview tasks.

4.5 Conclusion

Overall, the current findings did not provide conclusive answers to the research questions addressing distinctions between fantasy play in physical and virtual settings, the creation of fantasy play in virtual stimuli and the feasibility of the tabletop in supporting preschool children in enacting their fantasy. From the study, the author found that children experienced serious interaction difficulties using the DT multi-touch interactive tabletop device which probably disrupted their natural disposition towards fantasy play. Most of interaction issues observed in the study were of the following types:

- Children tended to put both hands on the tabletop screen whilst interacting with the tabletop application, resulting in object errors. Therefore, the researcher asked the children to put one hand behind their back while interacting with the tabletop, as successful operation of the tabletop required that it be touched with only part of the body at a time which is clearly restrictive for the children.
- Tendency of both children to try to drag the same object at the same time; a child tried to drag two objects on the same time and rest their forearm or other fingers on the tabletop to support their movement which also caused dragging errors.
- Children tapping the tabletop surface as they tended to select the object by tapping the object on the tabletop quickly.
- Some of the children faced difficulties when attempting to drag and make the object stick to their finger due to the small size of these objects.
- Children had difficulty when attempting to drag and point to the object with only one finger.
- Some of the children applied too much pressure when selecting and pressing the object, which produced squeaky sound from the table.
Children had difficulty in reaching objects which were far from their position at the tabletop, and sometimes tried to climb on the table to reach the object.

- Children tended to rest their feet while sitting on the stool and did not put their feet on the mat in the required position.

Despite this usability problem, some fantasy play bouts were still observed in the study. However, the evidence presented in this chapter clearly showed that too few examples of fantasy play were captured in the virtual environments for significant comparison. Interestingly, most of the children concentrated harder when moving the virtual objects rather than when playing with the tree house. The little evidence of fantasy play found in the virtual environment tended to focus on simpler stories compared to the fantasy bouts created in the physical environment. Moreover, physical objects tended to encourage frequent vocalisation, whereas children did not show the same behaviour when playing with virtual objects. Object substitution was rare in both conditions, possibly reflecting the developmental stage of the children (McLoyd, 1983). Furthermore, fantasy play bouts elicited by virtual stimuli appeared to involve a lower number of low structure objects than in the physical stimuli.

Poor interactive performance on the tabletop did not stop the children from liking it. This is evidenced by the smiling, laughing and length of the play time, which was not much different from the time spent with the real tree house. However, findings from the study show that children performed different games in the two conditions. Most play in the real environment concentrated around the tree house (e.g. arranging objects on the tree platforms, arranging stairs and building a small tower from blocks), and in particular around the rope, tree trunk, tree leaves and stairs (e.g. dolls bounced on stairs, dolls climbing the rope or tree trunk, dolls or other objects tied or hanging to the rope and attached to the tree leaves). Objects were frequently reorganised on the platforms and coordinated with each other (e.g. dolls were seated on chairs and watching TV).

In the virtual tree house condition, objects were moved independently and children tended to spread them randomly on the screen, with little interaction with the tree house. Children not engaging with the virtual tree could be due to difficulties of young children in understanding the 3D perspective of illustrations (Ackermann, 1996). The proportion of the open plan platforms of the tree house was quite small in relation to the
objects, which might have discouraged children from using them. In fact, the children did not recognise the similarity between the two environments.

Working with children and teachers from the start in brainstorming and developing the initial ideas benefits the researcher in understanding the needs and requirements of the target user (Hanna, Risden & Alexander, 1994). The pilot studies conducted before the actual study also gave an opportunity for the researcher to practice and to observe any further requirements or modifications needed in order to ensure the materials were ready to support the experiment.

However, transcribing and coding the class behaviour was quite difficult and challenging, as it required listening to children’s verbal comments which were recorded against surrounding noises. Some children were also distracted by the noisy environment during the interview session and were quite shy in the beginning of the interview session. Very little verbalisation was observed during the entire study. This may have reduced the possibility of producing fantasy play episodes. Despite the fact that moderate verbalisation is a common behaviour of preschool children (McLoyd, 1983; Ackermann, 1996; Striano, Tomasello & Rochat, 2001), the particular setting of the study may have disrupted this natural tendency. Indeed, the noisy environment may have inhibited verbalisation and vocalisation both in the physical and the virtual environments. The concentration of the children on the task at hand could be related to the lower level of verbalisation in the virtual tree house.

Based on the lessons learned in this study, a new application was designed to make the tabletop more engaging, adding more animations and sounds. It was thought that more than one opportunity to interact with the tabletop would encourage the children, as well as increase their performance in engaging with the virtual application during the play session. To maximise the success of the tabletop interaction, the setting was redesigned by:

- Resizing the size of virtual objects for easy handling.
- Removing all stools and allowing children to stand on the mat.
- Asking children to take off their shoes before playing for better connectivity with the tabletop.
Also, the following guidelines were applied in designing the next study:

- Arranging the session in a quiet room. It helped the children to be more focused on the study as the surrounding environment plays a large part in how the children performed the tasks. Besides, it helped the researcher to reduce complexity at transcribing and coding the children’s behaviours.
- Arranged a simple task as a warm-up session before the interview began to help the children who are shy to build their confidence. Working in pairs during the play session helps the children who were too shy to get involved in the task.

The next chapter will describe the details of procedures and report the results of empirical Study 2.
Chapter 5: Study 2 – The Magic House

This chapter reports testing the solutions to the interaction difficulties demonstrated in the first study, to see how the tabletop could offer an engaging experience for children. Ten children (aged 3 and 4) played in same-sex dyads with a Magic House application implemented on a Mitsubishi DT multi-touch interactive tabletop. They were invited to play with the application twice and all their behaviours were recorded for data analysis purposes. The study solved many of the interaction problems described in Study 1 (refer to Chapter 4) when children used the tabletop. Indeed, further examples of fantasy play were captured during both sessions. The findings suggest that virtual objects have the potential to foster fantasy play among young children.
5.1 Introduction

This chapter reports the second study, which was designed to solve some of the problems identified in Study 1 (refer to Chapter 4) and to address whether fantasy play is possible in virtual environments. Results from the study reported in the previous chapter indicated that users experienced difficulties when interacting with the Mitsubishi DT multi-touch interactive tabletop table, as children often struggled to drag objects displayed on the tabletop surface. A new application called The Magic House was designed in order to eliminate major problems which occurred in the previous study. The objective was to design a simple play environment which fostered fantasy play in children aged 3 and 4. Data was collected by observing children while they played with the study materials. Both quantitative and qualitative methods were used in data collection and analysis.

5.2 Method

5.2.1 Design of the Magic House

A new multimedia prototype named The Magic House was designed by the author and implemented in Macromedia Flash. The design was based on the idea of Striano’s doll’s house with rooms (Striano, Tomasello & Rochat, 2001). However, due to reduced geometrical complexity of the play environment, the design concentrated on a living room layout with some props. The objective was to design a simple play environment with a better interaction design which fostered fantasy play and solved some of the problems from Study one. The illustration of the Magic House was projected on to the tabletop screen (76cm L x 60cm W).

The design of the Magic House was based on a survey of a group of 3 children aged 3-7. The researcher talked informally with the children about their imagined living room. From the interviews, the ideas from the children were gathered and used as guidelines for the development of the Magic House. The ideas of their imagined living room were as follows:

- A simple large room with a big window on the right side with a day or a night view.
- A door with a cat flap at the bottom on the left side.
- A spider’s web next to the door.
- A set of male and female human dolls.
- A simple set of house related props (e.g. TV, table, lamp and vase).
- A magic wand that can be used to change or transform an object into another object.
- The *Lazy Town* and *In the Night Garden* video clips showed in the TV (popular children’s TV programs in the UK).

Then, based on all the ideas gathered from the children, the researcher designed the Magic House as illustrated in Figure 33.

![Figure 33: The Magic House](image)

A set of low- and high-structure objects was used in the study, based on McLoyd’s (1983) suggestions. The low-structure objects comprised a set of coloured blocks of several shapes (i.e. a yellow cylinder, a blue and a purple cube, a red triangle and a green rectangle). The high-structure objects included a wand, six human dolls (two females, two males and two babies) and house-related props consisting of a lamp, a table, a vase of flowers and two TVs with different video clips.

The magic wand and five low-level structure objects were provided at the bottom of the screen for children to play with. Each of the low-level structure objects was transformed into a high-level structure object when it was first moved into the room (associated with a twinkling sound of the magic wand). For example, the green rectangle changed into a girl doll, that waved and said “hello”, the purple cube changed into a flower vase, the red triangle changed into a coffee table, the blue box changed into a green TV set showing a short video clip from *Lazy town* (a popular TV series for younger children in
the UK) and the yellow cylinder changed into a boy doll, that waved and said “hi” (Figure 34).

All objects could be transformed again when they were touched by the magic wand in the room area (again associated with the twinkling sound of the magic wand). For instance, the boy changed into a girl and the girl could be changed into a baby, the flower vase changed into a lamp, the green TV set changed into a blue TV set showing *In the night garden* (another popular children’s TV series in the UK), the girl (the doll with the star on her shirt) changed into a boy, and the boy could be changed into a baby. The wand also transformed other pictures such as changing the window with the day view into a night view, the spider's web triggered an animation of a spider dropping from the web, and the cat flap triggered an animation of a cat chasing a mouse across the room. All objects were also associated with a set of multimodal features and produced a different sound every time they were moved in the room area. The table and the flower vase produced a simple sound (*dong*), the light switched on and produced a realistic sound (*click-click*), the TV set played the video clip and all dolls could wave and produce a simple sound (*ding*).

To solve the usability problems demonstrated in Study 1, the size of the objects was increased by 300% as compared to the *Tree House* application so that users could easily drag and move them around the tabletop space with their finger(s). For example, the size of the objects in Study 1 was increased from 30 pixels to 100 pixels in Study 2. Furthermore, the number of objects available on the screen was minimised, as not all objects in the previous study (the tree house environment) had been used by the
Chapter 5: Study 2 – The Magic House

children, who tended to concentrate on their favourite objects, such as dolls, the TV, the sofa and the flower vase.

5.2.1.1 DiamondTouch Multi-Touch Interactive Tabletop

The robust metal frame previously designed for Study 1 was re-used in this experiment to hold the DT multi-touch interactive tabletop and mount the projector (122cm from the table to the projector) out of the children’s reach. The metal frame was also attached to a little coffee table (45cm height from the floor), which was suitable for the children’s height, enabling them to reach all parts of the tabletop surface. However, the two plastic chairs provided in Study 1 were removed and the two receiver mats (one for each child) remained on the floor (Figure 35). The children were invited to take off their shoes before their play to ensure that their feet connected with the mats correctly at all times.

![Diagram of DiamondTouch multi-touch interactive tabletop setting]

Figure 35: DiamondTouch (DT) multi-touch interactive tabletop setting (Study 2)
5.2.2 Pilot study

Two series of pilot studies were performed:

- **Pilot study 1.** The first pilot study concentrated on the new setting of the tabletop, which was iteratively tested with a 3 year-old child accompanied by her parent in a usability laboratory of the Manchester Business School. During the test sessions, there were no signs of the usability problems seen in Study 1.

- **Pilot study 2.** The second pilot study concerned the new application designed for the study. Three children (aged 2½ - 3½, accompanied by their parents) were invited to play with the Magic House in a usability laboratory of the Manchester Business School. From the observation, all the children enjoyed playing with the application, and no major interaction problems were highlighted. However, the children still tended to put two hands on the table while operating with the tabletop and the experimenter frequently needed to remind them not to do so.

5.2.3 Participants

A total of 12 children (6 girls and 6 boys) aged 3-4 years old (mean = 47 months, SD = 1.7 months) were recruited from the Martenscroft Nursery School in Manchester (UK); they were all attending the nursery on a full-day basis, normally five days a week. The report by Ofsted, the official UK body inspecting schools (Martenscroft Nursery School Ofsted, 2008) states that this school is situated in a neighbourhood with high levels of social and economic disadvantage. The children came from a wide range of ethnic backgrounds, as shown in Table 15 (and refer to Appendix 7).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Mixed</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Asian or Asian British</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Chinese or Other Ethnic Group</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6</strong></td>
<td><strong>6</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>
Almost half of the children speak English as a second language, but all of them were able to communicate very well in English. A total of 7 children were reported as being from single child families and 5 had siblings. 50% of the parents worked in professional posts, 17% were students, 8% housewives, 17% were working casually and 8% were unemployed (refer to Appendix 8).

On the day of the study, 2 boys were absent. Therefore, the study involved a total of ten children (three dyads of girls and two of boys). All children were members of the same class and were familiar with each other.

5.2.4 Study Design

The children were invited to play with the Magic House (a virtual living room and a set of virtual objects displayed on the tabletop) twice (morning and afternoon sessions) for 10 minutes each.

5.2.5 Procedure

5.2.5.1 Evaluation phase

The study was carried out in one of the crèche rooms at the nursery school during school time. The general evaluation procedures were conducted as described in Chapter 3 (page 75). Throughout the experimental sessions, the environment was quiet as the room was only being used for the purpose of the study. The tabletop equipment was set up in available space in the corner of the room (Figure 36 and Figure 37).
The first session were conducted in the morning. All dyads were invited to take part in a training task as a warm-up session before starting to play. The training was similar to the task in Study 1 but with bigger balls; seven balls were displayed on the screen and the children were invited to drag them inside a red rectangular box (Figure 38). The training task procedures were conducted as described in Chapter 3 (page 76). This phase lasted a maximum of 108 seconds and the session ended earlier if the children showed signs of losing interest.
After the training phase, the spider dropped down from the middle of the top screen and introduced the Magic House saying, "Hello, my name is Dingle Dangle. Welcome to my Magic House. Find the cat chasing the mouse. Come on and play and have a lot of fun. You can change the moon into a sun. Drag the objects into my room. Wave the wand and say Bing! Bang! Boom!" The main experimenter assisted the dyads to explore and play with the application for approximately 10 minutes, showed any parts which were not discovered by the dyad, and helped them to become familiar with the application.

The second sessions were conducted in the same place in the afternoon. During these sessions, the experimenter left the dyads to play again with the Magic House for about 10 minutes with minimal supervision, and interrupted only when necessary and without needing to complete the training task.

The first 10 minutes of the play sessions were videotaped for analysis purposes using two cameras to capture the scene from two different viewpoints. The activity on the tabletop was also captured using the Camtasia Recorder software.

5.2.5.2 Interview phase

The interview sessions were conducted at the same study location and involved only 9 children (six girls and three boys), due to the two absentee boys and one boy who refused to take part on the day of the interviews. The interview procedures were conducted as described in Chapter 3 (page 77) except that children were asked to complete a simple puzzle as a warm-up session before the interviews began (Figure 39 and Figure 40).
5.3 Data Analysis

The general data analysis procedure was conducted as described in Chapter 3 (page 80). All videos of children’s play behaviour were transcribed and analysed, except for the variable of engaged objects which was insignificant in the current study as the whole screen was part of the play environment.
5.3.1 Sample description analysis

The sample description were analysed based on the procedures described in Chapter 3 (page 80).

5.3.2 Training phase analysis (virtual setting)

Camtasia Recorder software footage from a total of nine training sessions was analysed, based on the general training phase analysis procedures described in Chapter 3 (page 81).

5.3.3 Play phase analysis

The general video analysis procedure was conducted as described in Chapter 3 (page 81). A total of 18 video clips were used for the purpose of the analysis. The play scene that was shot with two camcorders (zoom-in and zoom-out) at the same time was combined in one movie (side by side). Nine pieces of Camtasia Recorder software footage were also used to analyse the activity on the screen.

5.3.3.1 Moving actions analysis

The first phase of the analysis concentrated on the moving actions where all objects moved by each child were captured. Each object and area of the play environment was also labelled with a specific number for easy recognition and analysis. The coding for the objects and area is demonstrated in Figure 41 and Figure 42. Actions were analysed based on the same action categories as in Study 1 (page 104). In the fine-grained analysis, an independent evaluator double-checked 20% of the videos and inter-rater reliability was 96%.
5.3.3.2  Fantasy play analysis

Children’s fantasy play was analysed, based on the fantasy play analysis procedures described in Chapter 3 (page 84). Some of 70% of the analysis completed by the researcher was checked by an independent evaluator and inter-reliability was 92%. In the case of disagreement, the researcher and the independent evaluator discussed and resolved all discrepancies.

5.3.3.3  Other observational behaviours analysis

Children’s other behaviours were analysed, based on the other observational behaviours analysis procedures described in Chapter 3 (page 85). An independent evaluator checked 20% of the analysis completed by the researcher. The inter-
reliability was 95% and all discrepancies were discussed and resolved. Refer Appendix 9 for basic quantitative data on behaviours.

5.4 Results

5.4.1 Sample description

In general, five out of the twelve children (one boy and four girls) were classified as having an imaginary companion and seven children (two boys and five girls) were identified as impersonators of character. A total of seven children were grouped as High fantasy (two boys and five girls), two children were grouped as Low fantasy (one boy and one girl) and three children (boys) were unclassified as they were absent.

A total of five High fantasy group children scored more than 50% and two children scored less than 50% in the imaginative play predisposition interview, while all Low fantasy group children scored more than 50% in the imaginative play predisposition interview. Table 16 presents the mean numbers of correct responses in the theory of mind task by children in the two groups. There was no significant difference between High and Low fantasy group scores in the theory of mind task, \((t(7) = 0.448, p > 0.05)\). The result was consistent with Study 1, as the average age for participants in this study was also under 4.

<table>
<thead>
<tr>
<th>Theory of Mind scores</th>
<th>High fantasy group (N=7)</th>
<th>Low fantasy group (N=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>High fantasy group</td>
<td>7.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Low fantasy group</td>
<td>7.3</td>
<td>2.1</td>
</tr>
</tbody>
</table>

* N = number of children

5.4.2 Training phase

The average training-phase time was 80 seconds (SD = 53 sec.). All children moved an average of six objects (small yellow and green balls) although one boy had a zero score due to his refusal to move any object during the training. At the beginning of the training, children concentrated hard on the task and some were a bit too shy. After a few successful attempts they became a little excited and asked for more objects to drag; the experimenter dragged balls out of the red box for the children to continue their dragging training. The warm-up session helped the children to become familiar
with the study environment and equipment, which resulted in a more collaborative and engaging environment as well as increasing their performance in the play phase.

5.4.3 Play phase

A total of five dyads participated in the first session but only four dyads in the second, as one dyad of boys refused to take part. The average of the evaluation time was 434 seconds (SD = 103.3 sec) in the first session and 495 seconds in the second session (SD = 133.7 sec), but this small increase in the second session was not significant (Wilcoxon Z = -0.135, p > 0.05). The distribution of evaluation times in both sessions ranging from 341 to 530 seconds in the Session 1 and from 307 to 600 seconds in Session 2.

5.4.3.1 General observations

All the children enjoyed playing with the application except for one boy who refused to play in the morning session; his session ended early as he started to cry in the middle of it. The same dyad included the one who refused to take part in the afternoon session, so only four dyads completed both sessions. Children were happy playing, possibly because the study was conducted in a private room without any distraction. From the observations, children were more comfortable playing with the application in the second session as they were already familiar with it and more confident in their actions and movements.

From the observation, rich evidence of verbalisation was recorded during the study, thus increasing the chances of revealing fantasy play. Most of the verbalisation was by female dyads, who actively talked to each other throughout most of both sessions. The following is an example of the active conversation:

[Ana (girl, 3 1/2 years) and Emma (girl, 3 1/2 years) play together with the Magic House]

Ana : I’m gonna do the.. baby again! (Drags the wand to the yellow cylinder block)
Ting!! Oh..
Emma : That’s not the baby.. the baby is in the box..
(Point the baby doll to the window and drags the wand to the baby doll. Baby doll changed into a girl doll)
Ana : What’s that Emma?
(Ana and Emma laugh)
Ana : I’ve got the boy! (Points to the boy doll)
Emma : I’ve got the girl! (Points to the girl doll)
Ana : My turn again!.. tuu dooo dooo..
Chapter 5: Study 2 – The Magic House

Emma: *No! You cannot do that!*

(Ana and Emma laugh)

However, evidence of silent play were also recorded, performed mostly by the male dyad during the play sessions. For example:

[Adam (boy, 4 years) and Emir (boy, 4 years) play together with the Magic House]

Emir: *(Looks at Adam and points at the wand)*

Adam: *(Drags the boy doll and taps the wand) ( Watches Emir)*

Emir: *(Drags the wand to the cat’s door – triggers the cat chasing the mouse animation and taps the wand)*

Adam: *(Drags the boy doll to living room) (Drags the wand to the boy doll and taps the wand)*

Emir: *(Watches Adam’s action)*

Adam: *(Taps the wand)*

(Adam and Emir try to drag the wand at the same time)

Emir: *(Drags the wand to the baby doll)*

Adam: *(Drags the lamp to the living room)*

5.4.3.2 Moving actions

Table 17 shows the frequency and percentage of moving actions for the virtual environment. Actions are classified as in Study 1:

<table>
<thead>
<tr>
<th>Table 17: Frequency and percentage of moving actions (Study 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session 1</strong></td>
</tr>
<tr>
<td>No movement</td>
</tr>
<tr>
<td>Failed movement</td>
</tr>
<tr>
<td>Correct movement</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Session 2</strong></td>
</tr>
<tr>
<td>No movement</td>
</tr>
<tr>
<td>Failed movement</td>
</tr>
<tr>
<td>Correct movement</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

The fine-grained analysis of the moving actions clearly showed that children were successfully moving objects in the *Magic House* prototype and that more than 90% of the total movements in both Session 1 and Session 2 were successful. The high percentage of successful moving actions was mainly due to a fall in the percentage of no movements as compared to Study 1. In Session 2, there was a slight improvement over Session 1 in terms of the percentage of correct movement.
5.4.3.3 Fantasy play

A total of 21 bouts of fantasy play occurred in Session 1, in all three of the girl dyads. In Session 2, a total of 26 bouts of fantasy play were found, and were performed by all four dyads (one boy and three girl dyads). Table 18 presents the frequency and the mean number of fantasy Themes, Object Substitutions and instances of Onomatopoeia per bout of fantasy play in the two experimental conditions. In general, it shows a consistent pattern.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Substitution</th>
<th>Onomatopoeia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq</td>
<td>Mean</td>
<td>Freq</td>
</tr>
<tr>
<td>Session 1 (N=21)</td>
<td>28</td>
<td>1.3</td>
</tr>
<tr>
<td>Session 2 (N=26)</td>
<td>34</td>
<td>1.3</td>
</tr>
</tbody>
</table>

N = number of fantasy bouts

From the general observations, the children tended to create most of their fantasy play themes relating to real persons (acted by the dolls). They also loved to use the virtual magic wand to transform or change things into objects that they desired (the evidence of the frequency used of the magic wand in both sessions as reported in Table 19). For example, they changed the boy doll into a girl doll or a baby doll. Very few examples of object substitution events were recorded during the evaluation sessions. The following scenario is an example from a dyad using the wand to change things and transforming the boy doll into a big brother to the baby doll.

[Bella (girl, 3 1/2 years) and Julie (girl, 3 1/2 years) play together with the Magic House]

Bella : I'm gonna change it? (Drags the wand to the girl doll. The girl doll changes into a boy doll) ihhh.. uuhhh.. I changed it to a boy.. eerghh.. I want mine to be changed…

Julie : (Taps the TV and drags the coffee table next to the TV. Taps the boy doll) Oh.. mine is a boy.. (Drags the boy doll to the window)

Bella : He he he.. aaaa.. you got this change… Magic! (Drags the wand to the boy doll. The boy doll changes into a baby doll)

……

Bella : Hmm.. have you got a baby, Julie?

Julie : Oh! Sit on there baby!.. (Drags the coffee table next to the baby doll)

Bella : No! She will fall and bang her head! He.. he.. OK.. the baby will.. Ahh.. can't move the baby (Tries to drag baby doll to the top of the coffee table)

Julie : There!.. (Points to the coffee table)

Bella : Sit over there! Sit! (Drags baby doll to top of coffee table)

Julie : Yeaahh.. she sit on it.. Oh boy! Big brother come down! (Tries to drag the boy doll closer to the baby)
Very few fantasy bouts were performed by low fantasy group children as compared to high fantasy groups in both sessions. High fantasy groups created 20 fantasy bouts in Session 1 and 24 fantasy bouts in Session 2, while the Low fantasy children only created one fantasy bout in Session 1 and two fantasy bouts in Session 2.

Overall, the children tended to prefer high structure objects as compared to low structure objects. The frequency and the mean number of times the magic wand, high structure and low structure objects were used in the study are shown in Table 19. In Session 1, dyads played significantly more with high structure objects than with low structure objects ($t(8) = 5.39$, $p < 0.05$). The same pattern was observed in Session 2, with the high structure objects used significantly more often than the low structure objects ($t(6) = 8.86$, $p < 0.05$).

<table>
<thead>
<tr>
<th>Object Structure</th>
<th>Session 1 (N=5)</th>
<th>Session 2 (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
</tr>
<tr>
<td>High Structure Object</td>
<td>390</td>
<td>78.0</td>
</tr>
<tr>
<td>Low Structure Object</td>
<td>52</td>
<td>10.4</td>
</tr>
<tr>
<td>Magic wand</td>
<td>336</td>
<td>67.2</td>
</tr>
</tbody>
</table>

* N = number of dyads

The data in Table 20 presents the frequency and the mean number of fantasy play components enacted with high and low structure objects. In Session 1, themes emerged significantly more frequently in the presence of high structure objects than of low structure objects ($t(8) = 1.99$, $p < 0.05$). The same occurred in Session 2, with dyads creating significantly more themes with high structure objects than with low structure objects ($t(6) = 2.96$, $p < 0.05$). Object substitution and instances of onomatopoeia occurred only in the presence of high structure objects and there was no evidence of them being enacted with low structure objects.
Table 20: The frequency and the mean of fantasy play components expressed per dyad in play sessions with High and Low structure play objects (Study 2)

<table>
<thead>
<tr>
<th></th>
<th>Themes</th>
<th>Substitution</th>
<th>Onomatopoeia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
<td>Sd.</td>
</tr>
<tr>
<td>Session 1 (N=5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Structure Objects</td>
<td>27</td>
<td>5.4</td>
<td>5.8</td>
</tr>
<tr>
<td>Low Structure Objects</td>
<td>1</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Session 2 (N=4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Structure Objects</td>
<td>38</td>
<td>8.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Low Structure Objects</td>
<td>1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* N = number of dyads

5.4.3.4 Social behaviours

Table 21 displays the number of dyads involved, the frequency and the average of the frequency over playtime for social behaviours in the two sessions. Overall, higher occurrences of positive behaviours were observed in both Session 1 (N = 140) and Session 2 (N = 94) than negative behaviours (Session 1 = 16, Session 2 = 34). Based on observations, more evidence of agreement was found in Session 1 than in Session 2, while a higher occurrence of disagreement was produced by dyads in Session 2 than in Session 1. The following is a discourse segment of children playing in their dyad, which illustrates agreement and disagreement collaborative behaviours.

Agreement:

[Bella (girl, 3 1/2 years) and Julie (girl, 3 1/2 years) play together with the Magic House]

(Bella and Julie smiling and dancing)
Julie : Ooo.. I want to do something!
Bella : Ooo yes! (Looking at Julie)
Julie : He he he.. teee teee teee,,,, (Drags the wand to TV)

Disagreement:

[Ana (girl, 3 1/2 years) and Emma (girl, 3 1/2 years) play together with the Magic House]

Emma : My turn.. hmm..
Ana : My turn! (drags the wand to the TV)
Emma : No! My turn!
Ana : My turn!
Emma : Mine!
Ana : Well.. again..
Emma : No!
Since there was only one magic wand, children needed to share it. The occurrence of asking for their turn was observed in both sessions (mainly produced by two girl dyads), when they waited and requested their turn. The tendency for children to contribute some ideas to their partner during both play sessions was also observed; for example, by suggesting actions to their partner; “Let’s put magic on it!”, “Drag that one!”, “Change it to baby!”. The results also show that the children tended to watch their partner more in Session 1 than in Session 2. This tendency was mostly seen when they were preoccupied with the actions created by their partner, or were waiting in anticipation for their turn.

However, several other social behaviours were observed in Session 1; examples of actions that occurred only once included asking the partner’s opinion (a child asked her partner about a suitable name for the baby doll), helping his partner (by reminding him to drag the object properly using fingers to avoid errors), asking the partner to stop playing and a child refusing to play (even after several attempts at encouragement from the demonstrator). Furthermore, 5 cases of the children trying to steal the object from their partner were observed in Session 1 and the behaviour increased to 6 cases in Session 2.

<table>
<thead>
<tr>
<th>Table 21: The number of dyads involved, the frequency and the average rate for social behaviours (Study 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive behaviours (7)</strong></td>
</tr>
<tr>
<td>No. of dyads</td>
</tr>
<tr>
<td>Agreement</td>
</tr>
<tr>
<td>Ask for their turn</td>
</tr>
<tr>
<td>Ask partner’s opinion</td>
</tr>
<tr>
<td>Ask partner to move object</td>
</tr>
<tr>
<td>Help partner</td>
</tr>
<tr>
<td>Suggest an action</td>
</tr>
<tr>
<td>Watch partner</td>
</tr>
<tr>
<td><strong>Negative behaviours (4)</strong></td>
</tr>
<tr>
<td>No. of dyads</td>
</tr>
<tr>
<td>Ask partner to stop</td>
</tr>
<tr>
<td>Disagreement</td>
</tr>
<tr>
<td>Refuse to play</td>
</tr>
<tr>
<td>Steal object from partner</td>
</tr>
</tbody>
</table>

** Average rate = (the mean of frequency of the behaviour of each dyad over their playtime in minutes) / number of behaviours for each category
5.4.3.5 Affective behaviours

Table 22 reports the number of dyads involved, the frequency and the average of the frequency over playtime for affective behaviours in the two sessions. This study demonstrated more evidence of positive affective behaviours such as dancing, followed by smiling, laughing and excitement in both sessions. Dancing was observed in the reaction of children when they listened and watched the video clip from the TVs. Little evidence of children excitedly jumping on the spot when they watched the video clips was noted in this study. Unexpected events surprised the children (e.g. when the wand touched the cat’s door, an animation of a cat chasing a mouse across the room appeared). In Session 1, a large amount of the dancing, smiling, laughing and surprise may be due to the children’s enjoyment when they played with the study materials for the first time.

However, the children tended to be frustrated when the feedback from the application did not respond as they wanted (e.g. the wand changed the boy into a girl and not a baby as they wanted it to). The evidence of frustration increased in Session 2 due to some of the children again being dissatisfied with the response. The evidence of anger was captured in Session 2 when a girl was angry with her partner who changed an object that she liked.

In Session 1, one of the participants was not really interested in playing and showed signs of boredom several times while watching his partner playing. This participant looked very sad and he cried in the middle of the session; the demonstrator terminated the play session and sent the dyad back to their class. No evidence of boredom, sadness or crying was found in Session 2.
Table 22: The number of dyads involved, the frequency and the average rate for affective behaviours (Study 2)

<table>
<thead>
<tr>
<th></th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
</tr>
<tr>
<td><strong>Positive behaviours (6)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dance</td>
<td>4</td>
<td>211</td>
</tr>
<tr>
<td>Excited</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Jump</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Laugh</td>
<td>3</td>
<td>53</td>
</tr>
<tr>
<td>Smile</td>
<td>3</td>
<td>59</td>
</tr>
<tr>
<td>Surprised</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td><strong>Negative behaviours (5)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anger</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Bored</td>
<td>1(*)</td>
<td>4</td>
</tr>
<tr>
<td>Cry</td>
<td>1(*)</td>
<td>1</td>
</tr>
<tr>
<td>Frustrated</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Sad</td>
<td>1(*)</td>
<td>3</td>
</tr>
</tbody>
</table>

** Average rate = (the mean of frequency of the behaviour of each dyad over their playtime in minutes) / number of behaviours for each category
(*) the same child

5.4.3.6 Attention distribution

Table 23 summarises the number of dyads involved, the frequency and the average of frequency over play time for attention distribution in both evaluation sessions. Overall, there was very little evidence of children concentrating when interacting with the tabletop. This may be because the objects were designed to be relatively large and they were easy to select and drag on the tabletop screen.

There was also more evidence of children looking at the demonstrator in Session 1 than in Session 2. This result is interesting as it coincides with the findings in the previous study, reflecting the confidence level of young children playing with the tabletop for their first time and the self-consciousness of being observed by the demonstrator before becoming familiar with the application in Session 2.
During the play time, and as in the previous study, the children tended to pause in their play, looking around and then continuing their play after a while; and there was no difference in either session. There was also a little evidence that children (two dyads in Session 1 and only one dyad in Session 2) checked the mat or were aware of their position when interacting with the table in both sessions. Furthermore, the result shows that there was only one incident of children peeping at the demonstrator’s PC; this was captured in Session 2, and there was no evidence of it at all in Session 1. However, there was an incident where two dyads looked at the projector while interacting with the tabletop and the demonstrator quickly reminded them not to do so for safety reasons.

The result showed evidence of children (two dyads with 13 cases in Session 1 and one dyad with 2 cases in Session 2) tending to play with their wristband during the play sessions. On some occasions, three dyads (two in Session 1 and one in Session 2) tended to play with the coloured shadow reflected on their hands from the projector, which indirectly distracted them as they had fun with it. For example, “Look!.. my hand is pink!”, “My hand is really purple.. my both hands.. and yours is brown!”. One dyad in Session 1 and one dyad in Session 2 were observed to walk away from the study materials during the play sessions.

Table 23: The number of dyads involved, the frequency and the average rate for attention distribution (Study 2)

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Frequency</td>
</tr>
<tr>
<td>Concentration</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Look around</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Look at mat</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Look at demonstrator</td>
<td>3</td>
<td>39</td>
</tr>
<tr>
<td>Look at projector</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Look demonstrator’s PC</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Play with hands &amp; shadow</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Play with wristband</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Walk away</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>71</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes
5.4.3.7 Interaction with the tabletop

Table 24 summarises the number of dyads involved, the frequency and the average of frequency over play time of interaction with the tabletop behaviours in the two sessions. With reference to the interaction behaviours, this study found little evidence of children putting their two hands on the table, in comparison to the previous study; the occurrence was reduced from eight cases in Session 1, produced by four dyads, to seven cases in Session 2 produced by only two dyads.

Other issues were the tendencies of both children trying to drag the same object at the same time (produced only by one different dyad in each session) and hide objects from the screen when the child (the same child in both sessions) dragged the object to the edge of the screen to make it disappear. There were also four cases where a child dragged an object around the screen, in Session 2. Children tapping the table had also been observed in both sessions as they tended to select the object by tapping on it quickly; this was slightly more frequent in Session 2 than in Session 1.

Another finding was that there was evidence of the children dragging the magic wand to the hot spots area to trigger the animation. Observation demonstrated that there were 62 cases of animation triggered in Session 1 and only 26 cases in Session 2. However, several interactions with the tabletop with only one occurrence were observed in Session 1; such as, trying to catch the animation by touching it quickly with their fingers, and sitting on the table and trying to change the object in the non-active area (e.g. dragging the wand to the object in the non-active area with the intention of changing it). When observing the videos, it was noted that all objects were moved into the active area by the participants. In Session 2, there was only one incident of a child dragging two objects at the time and a child tapping the avatar with her finger.
| Behaviour                          | Session 1 | | | Session 2 | | |
|----------------------------------|-----------|------|------|------------|------|
|                                  | No. of dyads | Freq. | Average rate (SD) * | No. of dyads | Freq. | Average rate (SD) * |
| Catch animated object            | 1         | 1    | 0.02 (0.05)        | 0            | 0    | 0.00 (0.00)         |
| Catch the avatar                 | 0         | 0    | 0.00 (0.00)        | 1            | 1    | 0.03 (0.05)         |
| Children drag the same object    | 1         | 2    | 0.05 (0.10)        | 1            | 3    | 0.15 (0.29)         |
| Drag two objects on the same time| 0         | 0    | 0.00 (0.00)        | 1            | 1    | 0.03 (0.05)         |
| Drag the object around the screen| 0         | 0    | 0.00 (0.00)        | 1            | 4    | 0.10 (0.20)         |
| Hide object from screen          | 1**       | 2    | 0.05 (0.10)        | 1**          | 5    | 0.13 (0.25)         |
| Sit on the table                 | 1         | 1    | 0.02 (0.06)        | 0            | 0    | 0.00 (0.00)         |
| Try to change object in non-active area | 1**       | 1    | 0.02 (0.05)        | 1**          | 2    | 0.05 (0.10)         |
| Tap the tabletop                 | 3         | 14   | 0.36 (0.38)        | 3            | 17   | 0.62 (0.72)         |
| Two hands on the tabletop        | 4         | 8    | 0.26 (0.31)        | 2            | 7    | 0.25 (0.29)         |
| Trigger animation in hot spot areas | 5       | 62   | 12.4 (11.2)       | 4            | 26   | 6.50 (7.33)         |
| **Total**                        | 5         | 91   | 2.40 (1.01)       | 4            | 66   | 2.50 (2.79)         |

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes
** the same dyad

5.4.3.8 Demonstrator involvement

Table 25 reports the number of dyads involved, the frequency and the average of the frequency over play time for demonstrator involvement behaviours in the two sessions. Demonstrator and children interaction in Session 1 was relatively high as the children were experiencing the tabletop and the application for the first time. In addition, the demonstrator actively encouraged the children to explore the application and other extra features, such as the function of the wand which could twist the object into another object, and the use of several hot spots which triggered animations. In Session 2, the demonstrator let the children play by themselves and only interrupted when needed.

Overall, there was very little evidence of demonstrator involvement, mainly when the demonstrator needed to remove the children’s hands from the table to avoid errors, and this occurrence was reduced in Session 2. However, the demonstrator still needed to remind children to keep their feet properly on the mat, maintain only one hand on the table and use the wand to change the object.
### Table 25: The number of dyads involved, the frequency and the average rate for demonstrator involvement (Study 2)

<table>
<thead>
<tr>
<th></th>
<th>Session 1</th>
<th></th>
<th>Session 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Frequency</td>
<td>Average rate (SD) *</td>
<td>No. of dyads</td>
</tr>
<tr>
<td>Encourage participant</td>
<td>5</td>
<td>107</td>
<td>2.98 (1.63)</td>
<td>3</td>
</tr>
<tr>
<td>Remind participant</td>
<td>5</td>
<td>25</td>
<td>0.79 (0.89)</td>
<td>4</td>
</tr>
<tr>
<td>Remove participant's hand(s)</td>
<td>3</td>
<td>7</td>
<td>0.25 (0.41)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5</strong></td>
<td><strong>139</strong></td>
<td>4.02 (2.22)</td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

#### 5.4.3.9 Other behaviours

Table 26 reports the number of dyads involved, the frequency and the average of the frequency over play time for other behaviours in the two sessions. Overall, children expressed various kinds of unexpected supplementary voices or sounds, which were not related to the fantasy play, in both sessions. For example, “tuu tuu tuuuu”, “dee deeeeee”, “eeeiii”. Twenty one cases were found in Session 1 and nineteen cases in Session 2.

### Table 26: The number of dyads involved, the frequency and the average rate for other behaviours (Study 2)

<table>
<thead>
<tr>
<th></th>
<th>Session 1</th>
<th></th>
<th>Session 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Frequency</td>
<td>Average rate (SD) *</td>
<td>No. of dyads</td>
</tr>
<tr>
<td>Voice expression</td>
<td>3</td>
<td>21</td>
<td>0.51 (0.77)</td>
<td>3</td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

#### 5.4.4 Interview phase

Most of the children were quite shy at the beginning of the session but they were more comfortable when they started to play with the puzzle during the warm-up session. During this warm-up session, interestingly some of the children were captured finishing the puzzle just by matching and pairing the puzzle by the puzzle’s shapes but not matching and pairing based on shapes and pictures that were connected together. The privacy of the room provided a calm environment for children to focus on the interview tasks. The results of the interview sessions are reported in the sample description section.
5.5 Conclusion

In general, the *Magic House* prototype solved many of the interaction problems faced by participants in Study 1, demonstrating that the tabletop can be operated by children as young as 3. From the observation, the research findings showed that:

- Larger targets and a simpler graphical environment helped the children to interact easily with the tabletop surface.
- Children experienced better connectivity with the tabletop because all stools were removed and children did not sit on a chair while interacting with the application. Furthermore, the children did not mind being asked to remove their shoes to stand on the mat.

The study findings also suggest that virtual objects can foster fantasy play whenever appropriate interaction design allows children to play with them. Fantasy play occurred much more frequently in Session 2 (mean number of bouts per child mb = 2.1 Session 1; mb= 3.2 Session 2). The actual number of children who engaged in fantasy play also increased significantly, reaching 100% in Session 2. The following is an example of fantasy play enacted by one dyad during the evaluation session.

[Lily (girl, 3 ½ years) and Jane (girl, 3 ½ years) play together]

Lily : *Two babies.* *(Two virtual baby dolls are displayed on the screen)*
Jane : *No. Not two babies.*
Lily : *OK. This is baby.* *(Points at baby A)*
   *This is sister because this one is old enough* *(Points at baby B)*
Jane : *No. I need a sister!*
Lily : *OK. I’ll change it.* *(Lily changes the virtual baby into a virtual girl by using the magic wand)*

Analysis of the fantasy play revealed that High fantasy groups produced more evidence of fantasy bouts than Low fantasy groups. In addition, most of the fantasy play themes performed by children in both sessions were associated with high structure objects rather than low structure objects, which is consistent with McLoyd’s (1983) findings. This could be illustrated by children tending to create most of their fantasy play relating to real people (acted by the dolls) such as brothers, sisters and babies (Hughes, 2010). However, it appears to be contrary in terms of object substitution and onomatopoeia where there was no evidence of low structure objects being used by children in both sessions. Overall, the children tended to use high object structures more than low object structures in their play. Analysis of the children’s social and affective behaviours
Chapter 5: Study 2 – The Magic House

revealed that positive behaviour was more frequent more than negative behaviour in both sessions.

In general, sets of objects were provided at the bottom of the screen allowing the children to access the object easily as the position was closer to the children, which is supported the findings of Rick, Harris, Marshall, Fleck, Yuill & Rogers (2009). A high occurrence of the children tending to use the magic wand was observed. This was so they could transform or change the things into objects that they desired, as not all objects were visible on the screen at the same time for them to play with. There was also evidence of the children being frustrated and dissatisfied when the application feedback did not respond as they wanted. However, children enjoyed dragging the magic wand to the hot spots area to trigger the animation.

From the general observations, the higher levels of verbalisation observed in this study could be accounted for by the difference in the study environment compared with Study 1. In this study, the room provided was more private and quiet than in Study 1, offering a convenient environment for the children to concentrate on the evaluation task without any distraction. Alternatively, it could equally well have been caused by the difference in design of the applications and individual differences between children. McLoyd (1983) has posited a correlation between fantasy play and social background of the children. However, that the schools used in these studies were located in areas with similar levels of socio-economic disadvantage; therefore, it seems unlikely that differences in the socio-economic background of the children could explain the improved results of Study 2. The involvement of children from the early stage of the study (as in Study 1) contributed initial ideas in developing the Magic House application and also helped the researcher to gain and understand the needs of the target user. The pilot sessions also helped the researcher to test the study materials and to rehearse the study procedure before the actual session.

The study provided two sessions for children to play with the application, allowing them more time to explore it and become familiar with the tabletop setting. The children showed more confidence in playing during the second session, with minimal supervision and interruptions only when necessary. This is shown by the duration of play time in this study; it lasted almost three minutes longer than the average play time in Study 1. More importantly, most of this time was spent by actually playing with the application rather than attempting to operate it. A simple puzzle task conducted as a
warm-up session before the interview helped the children who were shy to be more confident to take part in the session. However, the evidence of children looking at the projector during the play session prompts another safety issue that needs to be considered.

Based on the lessons learned in the study reported in this chapter, further studies are required in order to understand the similarities and differences of fantasy play in physical and virtual conditions, and what exactly makes children engage spontaneously in complex fantasy play creation with virtual stimuli. The following guidelines were proposed for designing the next study:

- Modification to the projector setting of the tabletop for children’s safety purposes.
- Organise the study in a private and quiet room (as in Study 2), but face the demonstrator’s PC away from the children to avoid any distraction for the children to concentrate on the task.
- Ask children to stand on the mat for better connectivity with the tabletop (as in Study 2).
- Allow more time (at least two sessions) for the children to play, explore and become familiar with the tabletop setting (as in Study 2).
- Design a new application with a larger size of virtual objects for easy handling and adding animations and sounds to create more engaging tabletop play environment (as in Study 2). Locate the objects closer to the user and visible on the screen for easy access together with some hot spot areas for them to trigger the animation.
- Arrange a simple task before the interview session to help children who were shy to get familiar and confident in performing the task (as in Study 2).

The next chapter will describe the details of procedures and report the results of empirical Study 3.
Chapter 6: Study 3 – The Farm (Physical vs. Virtual)

This chapter presents the empirical study designed to investigate fantasy play in a physical and a virtual environment. Ten same-sex dyads of children (aged 3 and 4) were observed playing with physical farm toys and their virtual implementation on a Mitsubishi DT multi-touch interactive tabletop.
Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

6.1 Introduction

This chapter reports the third study that was conducted in the research. The study provided two settings for the children to play with. The first setting employed a real farm set with physical objects, and the second a virtual farm set with virtual objects implemented on the Mitsubishi DT multi-touch interactive tabletop device. It aimed to investigate the possibility of spontaneous fantasy play by children aged 3 and 4 using real and virtual toys, by comparing the observed behaviours in the two environments. This study also aimed to explore what makes children engage spontaneously in fantasy play creation with virtual stimuli. Data was collected by observing children playing with both materials. Both qualitative and quantitative analyses were performed.

6.2 Method

6.2.1 Design of The Farm

In this study, children were exposed to two different environments: the physical farm set and the virtual farm set. The virtual farm set was designed in Macromedia Flash supported by DTFlash scripting and implemented on a Mitsubishi DT multi-touch interactive tabletop. The idea of using the farm set in the study was based on observation of children (aged 3 - 5) who attend the Echoes Day Nursery in Manchester. During the observation session, the nursery key worker exposed two sets of animal toys (farm and jungle animals) on two different tables during nursery play time. The tables were located next to each other and supervised by one key worker. The farm animal toys consisted of pairs of ducks, cows, horses, pigs, sheep and chickens. The jungle animal toys consisted of pairs of lions, giraffes, elephants, monkeys and tigers. Twenty children participated in the observation session for around 15 minutes. From the observation we found that the children preferred to play with the farm animals. At the end of the observation, they were asked to name their three favourite farm animals. Ducks, horses and sheep were the most preferred. Therefore, these animals were selected as the animal characters in the study apparatus.

Then, a low fidelity paper based prototype was designed based on a set of favourite farm animals which was previously suggested by the nursery children in a simple farm setting. The low fidelity prototype consisted of an A4 sized picture of the farm environment featuring a green field, a pond, a sun and clouds (Figure 43). A set of farm animals (ducks, horses and sheep) and two farmers were provided for children to play...
with. The low fidelity prototype was used in the informal discussion sessions with six children (two boys and four girls) aged 3 – 6. The sessions were conducted in the living room of the participant’s family or family friend’s house. The low fidelity prototype was arranged in the middle of the living room for the children to play with. The first session involved two male children aged 3 and 4, the second session involved two female children both aged 4, and the third session involved two female children aged 4 and 5. All the children played with the low fidelity prototype for about 10 minutes. Overall, the play sessions revealed that all children enjoyed playing with the prototypes.

![Low fidelity prototype](image)

**Figure 43: Low fidelity prototype**

From the informal discussion sessions with the children, the children suggested additional ideas of the new farm setting as follows:

- Provided a family set due to the creation of the characters of mummy, daddy and children.
- Adding hills and paths for the horses to play around.
- A bottle to feed the baby animal.
- Some trees as props.
- Adding the weather elements such as rain and night time, to change the play environment (for virtual setting only).
- Music such as *Old McDonald* song which was observed, sang by one of the children (for virtual setting only).
6.2.1.1 Physical farm

For the purposes of the study, a real farm environment was designed and built by the author (Figure 44). The layout of the farm environment was designed using cardboard and coloured paper. The environment consisted of two cupboard panels attached to a coffee table (90cm L x 60cm W x 45cm H). The size of each panel was (75cm L x 60cm W). The first panel was designed as a green field (represented by a piece of green paper) which featured a blue pond (represented by a couple of pieces of blue paper) located on the left side and a path with two junctions (represented by brown paper); the panel was attached horizontally and carefully taped to the surface of the coffee table. The second panel was designed and attached vertically on the side of the coffee table; it featured scenery with two hills (represented by green paper) with the background of a blue sky with four white clouds and a bright yellow sun.

A set of farm animal toys and human farm family toys were used and arranged on the white border around the field on the table for children to play with, as shown in Figure 44. The set of objects used is illustrated in Figure 45.

- **Human farm family set** comprised a farmer, his wife, his daughter and his son.
- **Horses family set** comprised a stallion, a mare and a foal.
- **Sheep family set** comprised a ram, a ewe and a lamb.
- **Ducks family set** comprised two ducks and one duckling.
- **Other objects** comprised a baby’s plastic bottle and a replica of two trees.
6.2.1.2 Virtual farm

A virtual model of the farm set was designed by the author and implemented in Macromedia Flash (Figure 46). The image of the virtual farm set was projected on the tabletop screen (76cm L x 60cm W). The 2D drawings of the virtual farm set were illustrated to look as closely as possible like the real farm environment and the real farm toys, including the shape, colour, proportions and dimensions. Large objects (approximately the size of more than 80 pixels) were designed so that the users could easily drag and move them around the tabletop surface using their fingers.

A simple menu bar was provided at the bottom of the screen for children to play with in order to change the play environment (Figure 46). The menu consisted of five icons (Figure 47):
- Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

- Sun, set the environment into a sunny day with a background of birdsong (Figure 48-a).
- Moon, set the environment to night time with a moon and stars blinking in the sky and all animals and humans sleeping (Figure 48-b).
- Umbrella, set the environment to a rainy day with grey sky and rain pouring on the ground; all the humans wore raincoats (Figure 48-c).
- Clear, reset the screen and set all objects back to their original position (Figure 48-d).
- Sound, played the music of a group of children singing an *Old McDonald* song.

![Figure 47: The menu (Study 3)](image)

![Figure 48: Farm environment: (a) day time; (b) night time; (c) rainy day; (d) screen reset](image)
All objects were associated with a set of multimedia features and produced a different sound when moved within the active area (other than the white border area and the menu block), based on the type of objects. The farmer said a word ('hello'), the farmer's wife said ('upsy daisy'), the boy said ('yeehaa!'), the girl said ('play with me!'), the horses made a sound ('neighhhh'), the ducks made a sound ('quack!'), the duckling made a sound ('quack! quack!'), the sheep made a sound ('baaaa'), the bottle made a sound ('tingling') and there was a simple sound ('plop') for trees.

Objects also performed animations when moved into specific hot spot areas such as the pond, the path (next to the pond) and the grass (with the sign of the sheep) as marked in grey colours, as shown in Figure 49; for example, the ducks swimming in the pond, the horses and the sheep drinking from the pond, the human sailing on a little boat, the bottle and the tree floating on the pond, every time the appropriate object was moved into the pond. The lamb bounced on the grass and the sheep ate the grass when it was moved on to the grass hot spot (with the sheep signboard); horses galloped on the path when they were moved on to the path hot spot (next to the horse signboard). Certain objects prompted animations when they overlapped. For instance, when any human dolls overlapped with any horses, a short animation of a human riding a horse appeared on the path, and when the foal or the lamb overlapped with the bottle, there was a short animation of the animal feeding from the bottle. All the ideas for the animations were based on the observations of movements and actions performed by the children during the informal discussion sessions.

Figure 49: The hot spot areas (Study 3)
6.2.1.3 DiamondTouch Multi-Touch Interactive Tabletop

The robust metal frame designed for Study 1 (refer to Chapter 4) and used in Study 2 (Chapter 5) was re-used in this experiment to hold the DT multi-touch interactive tabletop with the high-mounted projector. However, the mirror previously used to reflect the image from the projector on to the tabletop surface in Studies 1 and 2 was removed. A new projector holder was designed and attached to the metal frame so that the image was projected directly on to the tabletop surface (Figure 50). The metal frame was attached to a little coffee table (45cm height from the floor) as before. The children were again invited to take off their shoes to ensure that their feet connected with the mats at all times.

![Diagram of DiamondTouch (DT) multi-touch interactive tabletop setting (Study 3)](image)

Figure 50: DiamondTouch (DT) multi-touch interactive tabletop setting (Study 3)

6.2.2 Pilot study

Three series of pilot studies were conducted during the design of the experimental materials.

- **Pilot study 1 (DT multi-touch interactive tabletop).** The first pilot study focused on the new setting of the DT multi-touch interactive tabletop (Figure
51). A total of two adults and two children (accompanied by parents) were invited to play with the tabletop in a usability laboratory of the Manchester Business School. The first session involved the adults (a female and a male) and the second session two female children (aged 3 and 4). During the sessions, all participants were invited to play with the veggie interactive application (previously used in pilot Study 1) on the DT multi-touch interactive tabletop for 5 minutes. They were required to destroy objects that moved around the screen by pressing the fire button. In general, the new tabletop setting provided an enjoyable environment for users to play with the software and no problems were discovered during the session.

Figure 51: Pilot study for DiamondTouch (DT) multi-touch interactive tabletop setting

- **Pilot study 2 (physical farm).** Two female children (aged 2 ½ and 4) were invited to play with the first prototype of the physical farm setting for approximately 10 minutes (Figure 52). The session was conducted in the usability laboratory of Manchester Business School and participants were accompanied by their parents. The first prototype of the physical farm consisted of a single panel of the environment, featuring a green field, a pond and a path. Overall, children enjoyed playing with the toys. However, the children actively moved around the table while playing, suggesting that panels placed vertically on each side would be necessary to prevent the majority of this movement.
Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

- Pilot study 3 (physical and virtual farm). A sample of four children (aged 3-6) accompanied by their parents were invited to play with the experimental apparatus (both physical and the virtual farm implemented on the DT multi-touch interactive tabletop) in the usability laboratory of Manchester Business School (Figure 53).

The physical materials were located in the middle of a small room and the DT multi-touch interactive tabletop was located in an adjacent small room. The first session involved a female child and a male child (aged 3 and 4) and the second session involved two female children (aged 4 and 6). All children played with both physical and virtual farms for about 10 minutes each, and in general enjoyed both.
6.2.3 Participants

The participants were 20 children (ten girls and ten boys) who attend the nursery on a full-day basis, normally five days a week, at Martenscroft Nursery School, in Manchester (UK). The children ranged in age from 41 months to 59 months (mean = 49 months, SD = 4.1 months). In terms of ethnicity, the children come from a wide range of backgrounds, as shown in Table 27 (refer also to Appendix 10).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Mixed</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Asian or Asian British</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Black or Black British</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Chinese or Other Ethnic Group</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>10</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

Some of the children speak English as their second language, but all of them are fluent English speakers. A total of 11 children were reported to have siblings, nine were reported as the only child in the family, and 14 children were reported as the first child in the family. In terms of parents’ occupations, 30% were professional, 25% were housewives, 25% did casual work, 15% parents were students, 5% were unemployed and only one person gave no response (refer to Appendix 11).

On the day of the study, one girl was absent, so the study involved 19 children (nine girls and ten boys). Before the evaluation, the class teacher paired all the children, based on existing same-sex friendships, to support collaborative play. One of the girls was requested to play twice in order to replace the absent child. Therefore, all children played in pairs.

6.2.4 Study Design

The study was based on a within-subject design (setting: physical vs. virtual). The order of the play session was counterbalanced across dyads and gender. During the morning session, all children were invited to play with both physical and virtual (Session 1) settings for 10 minutes each. In the afternoon session, they were invited to play only with the virtual (Session 2) setting for another 10 minutes. In the physical
setting, children were provided with the physical farm setting and a set of farm animal replicas. In the virtual setting, they were invited to play with the virtual farm setting and virtual farm animals displayed on the DT multi-touch interactive tabletop.

6.2.5 Procedure

6.2.5.1 Evaluation Phase

Each dyad was evaluated, one at a time, during school time in a private room on the school premises. The general evaluation procedures described in Chapter 3 (page 75) were followed. The physical and virtual farms were located next to each other, but only one could be seen at any one time. The setting of the study is shown in Figure 54 and Figure 55.

![Diagram of Study 3 setup (a)](image)

**Figure 54: The layout of the Study 3 setup (a)**
In the physical setting, the researcher simply introduced the task of the study at the beginning of the session and invited the participants to play with the study materials. In the virtual Session 1, all dyads were asked to take part in a short training task as a warm-up session before starting to play. A training task similar to those used in Studies 1 and 2 was used: seven differently coloured balls were displayed on the screen, and the children were invited to drag them into a rectangular box (Figure 56). The training sessions were conducted as described in Chapter 3 (page 76).

After the children had finished the training phase, the play session begin with the spider (avatar) dropping down from the middle of the top screen and introducing the farm saying, “Hello, my name is Dingle Dangle. Welcome to the Farm. Drag the object into
the picture. Touch the symbol to change the scene. You can turn on the music or touch the clear button to start again. Have fun!"

All play sessions were observed and videotaped for analysis purposes. Two camcorders were used to capture all children’s behaviours and actions (as shown in Figure 55). One camera was set up to record all activities from a distance while the other was used to focus closely on the children’s facial expression and hand movements. The activity on the tabletop screen was captured using the Camtasia Recorder software.

6.2.5.2 Interview Phase

A total of 19 children (nine girls and ten boys) completed the interview task; one girl was absent. The same interview method was applied as described in Study 2, with detailed interview procedures as described in Chapter 3 (page 77). The interview setting is shown in Figure 57.

![Figure 57: Interview setting and materials (Study 3)](image)

6.3 Data Analysis

The general data analysis procedure was conducted as described in Chapter 3 (page 80).

6.3.1 Sample description analysis

The sample description were analysed based on the procedures described in Chapter 3 (page 80).
6.3.2 Training phase analysis (virtual setting)

Camtasia Recorder software footage from a total of ten training sessions was analysed, based on the general training phase analysis procedures described in Chapter 3 (page 81).

6.3.3 Play phase analysis

The general video analysis procedure was conducted as described in Chapter 3 (page 81). In the physical condition, a total of 20 video recordings were analysed. The play scene shot simultaneously with two camcorders (zoom-in and zoom-out) was combined into one movie (side by side). In the virtual condition, 20 pieces of Camtasia Recorder footage and 20 video recordings were analysed.

The area of the farm set was divided into several sections and each of the objects was labelled with a unique number for easy recognition and data analysis process (Figure 58 and Figure 59).

![Figure 58: Area grid coding scheme (Study 3)](image-url)
6.3.3.1 Fantasy play analysis

Children’s fantasy play was analysed, based on the fantasy play analysis procedures described in Chapter 3 (page 84). An independent evaluator checked 20% of the analysis completed by the researcher. The inter-rater reliability was 94%. Further fantasy play analyses were conducted in order to understand how the features of technology and the software product stimulated fantasy play. A selection of excerpts where the fantasy play occurred were analysed, based on what objects the children were playing together with, their actions and verbalisation.

An independent evaluator checked 20% of the analysis completed by the researcher. The inter-rater reliability was 95%. In the case of disagreement, the researcher and the independent evaluator discussed and resolved all discrepancies.

6.3.3.2 Other observational behaviours analysis

Children’s other behaviours were analysed, based on the other observational behaviours analysis procedures described in Chapter 3 (page 85). An independent evaluator checked 20% of the analysis completed by the researcher and inter-rater reliability was 96%. All other discrepancies were discussed and resolved. Refer Appendix 12 for basic quantitative data on behaviours.
6.4 Results

6.4.1 Sample description

In general, none of the children met the criteria for having an imaginary companion due to: (a) a total of six children mentioned that they had imaginary companions, but their parent did not report the child’s imaginary companion or provide any information in the questionnaires; (b) a total of three children were reported by their parents to have an imaginary companion, but the child did not mention one; (c) a total of thirteen children reported by not having an imaginary companion. A total of thirteen children (eight boys and five girls) were classified as impersonator characters, six children (two boys and four girls) were classified as non-impersonators and one girl was absent and categorised in an unidentified group.

Thirteen children were grouped as High fantasy (eight boys and four girls), six children (two boys and four girls) were grouped as Low fantasy (children who had neither an imaginary companion nor impersonated character), and one girl was categorised in an unidentified group as she was absent during the interview and evaluation sessions. Table 28 reports the performance of High and Low fantasy groups in the imaginative play predisposition interview. A total of seven High fantasy group and two Low fantasy group children scored more than 50% (indicating their interests were more on fantasy oriented play). A total of six High fantasy group and four Low fantasy group children scored less than 50% (indicating their interests were more on reality oriented play).

<table>
<thead>
<tr>
<th></th>
<th>High fantasy group (N = 13)</th>
<th>Low fantasy group (N = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scored &gt; 50%</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Scored &lt; 50%</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

* N = number of children

Table 29 reports the mean numbers of correct responses on the theory of mind task by High and Low fantasy groups. There was no significant difference between the theory of mind scores among High and Low fantasy groups (t(17) = 0.083, p > 0.05). These results contradict the findings of Taylor and Carlson (1977) on theory of mind scores among High and Low fantasy 4 year-olds.
### Table 29: Mean Theory of Mind task scores of children in High and Low Fantasy groups (Study 3)

<table>
<thead>
<tr>
<th>Theory of Mind scores</th>
<th>High fantasy group (N = 13)</th>
<th>Low fantasy group (N = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>6.4</td>
<td>6.3</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*N = number of children

6.4.2 Training phase (virtual setting)

The training phase lasted an average of 43 seconds (SD = 10.3 sec.) in which children moved an average of 3 objects (small purple and pink balls). At the beginning of the training, some children were rather too shy. Overall, the warm-up session helped the children to become more confident and familiar with the study materials and environment, which encouraged them to be more collaborative and increased their play performance in the actual evaluation time.

6.4.3 Play phase

A total of 10 dyads participated in all sessions. The average of the evaluation time was 465 seconds (SD = 143.4 sec) in the physical farm session, 415 seconds (SD = 95.9 sec) in the virtual farm Session 1 and 524 seconds (SD = 88.2 sec) in the virtual farm Session 2. According to Wilcoxon test, there was no significant difference between physical and virtual Session 1 (Z = -1.479, p > 0.05). However, a Wilcoxon test revealed that the playtime of virtual Session 2 was significantly higher than of virtual Session 1 (Z = -2.803, p < 0.05). There was a wide distribution of evaluation times in all conditions ranging from 130 to 600 seconds in the physical farm session, from 278 to 595 seconds in virtual Session 1 and from 313 to 600 seconds in virtual Session 2.

6.4.3.1 General observations

All the children enjoyed and were comfortable playing with the study materials, most probably because the study was conducted in a quiet private room without any distraction. However, at the beginning of the first session, some were too shy to play when they were observed by the researcher. After a few minutes they were more relaxed and comfortably playing the game. In addition, children were more confident in the second session of the virtual phase as they were already familiar with it and confident in their actions and movements.
Overall, rich evidence of verbalisation was observed during this study, as in Study 2, increasing the chances of enacting fantasy play. Both male and female dyads actively talked to each other throughout most of the sessions. One of the active conversations went as follows:

Joe (boy, 4 years) and Tom (boy, 4 years) play together with the virtual farm

Joe : Haa.. this.. (Presses the night button)
Tom : ( Watches Joe) T
(Joe and Tom smile and look at the demonstrator)
Tom : We want to stay here with mummy... bed time! (Drags the farm lady to the grass next to the boy)
(Joe and Tom smile and look at the demonstrator)
Tom : We go home with the space ship.. wuuuuuuuu.. (Moves his hand over his head pretending his hand is the space ship) and fly there (presses the day button)
Joe : Its supposed to be night!

Evidence of silent play was also observed as in Study 1 and 2, performed by some of the male and female dyads during the play sessions. For instance:

Matt (boy, 4 years) and Ken (boy, 4 years) play together with the virtual farm

Matt : (Looks around)
Ken : (Drags the girl human to the pond) (Drags the baby horse to the grass)
Matt : (Drags the boy human to the pond) (Watches Ken)
Ken : (Hides Tree1 out of screen)
Matt : (Presses the night button)
Ken : (Presses the music button)
Matt : (Presses clear button)
Ken : ( Looks at the demonstrator)
Matt : (Presses the music button)
Ken : (Presses the rain button)
Matt : (Watches Ken)
Ken : (Presses the night button) (Smiles and looks at the demonstrator)

---------------------------------------------

Dan (boy, 3 1/2 years) and Harris (boy, 4 years) play together with the physical farm

Dan : (Picks the daddy horse and puts it on grass behind the daddy human)
Harris : (Picks the bottle and Tree1 from the grass and puts them in the pond)
Dan : (Plays with his wristband) ( Watches Harris)
Harris : (Picks the mummy horse and puts it next to the daddy horse)
Dan : (Picks Tree1 and puts it next to the baby duck)
Harris : (Bounces the baby sheep on the pond)
Dan : (Moves the baby horse and puts it next to the mummy horse)
Harris : (Looks around)
6.4.3.2 Fantasy play

A total of 56 fantasy play bouts occurred in the physical session. These were performed by 9 out of 10 dyads (five boy and four girl dyads). In virtual Session 1, a total of 35 fantasy bouts were found, performed by 6 out of the 10 dyads (three boy and three girl dyads) and in virtual Session 2, a total of 54 fantasy bouts were recorded, performed by 9 out of 10 dyads (five boy and four girl dyads).

Overall, a total of 37 fantasy bouts were created by the High fantasy groups in the physical session (seven boys and three girls), 22 fantasy bouts in virtual Session 1 (four boys and two girls) and 29 fantasy bouts in virtual Session 2 (six boys and three girls). The Low fantasy group created 19 fantasy bouts in the physical session (two boys and two girls), 13 fantasy bouts in virtual Session 1 (two boys and two girls) and 25 fantasy bouts in virtual Session 2 (two boys and two girls).

Table 30 presents the frequency and the mean number of fantasy bouts produced by High fantasy and Low fantasy groups in the three experimental sessions. The t-test revealed that there was no significant difference between High and Low fantasy groups in physical session (t(17) = -0.203, p > 0.05), in virtual Session 1 (t(17) = -0.393, p > 0.05) or in virtual Session 2 (t(17) = -1.592, p > 0.05). In general, it shows the improvement of fantasy bouts performance by both groups in the virtual Session 2 as compared to the virtual Session 1. The increment by low fantasy group in the virtual Session 2 may be due to the children becoming familiar with the setting and more confident to perform their play.

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
<td>Freq</td>
</tr>
<tr>
<td>High fantasy group</td>
<td>37</td>
<td>2.8</td>
<td>22</td>
</tr>
<tr>
<td>(N=13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low fantasy group</td>
<td>19</td>
<td>3.2</td>
<td>13</td>
</tr>
<tr>
<td>(N=6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>3.5</td>
<td>35</td>
</tr>
</tbody>
</table>

* N = number of children

The total of 145 fantasy bouts observed in all sessions produced numerous themes, substitutions and examples of onomatopoeia. Table 31 reports the frequency and the mean number of fantasy Themes, Object Substitutions and instances of Onomatopoeia per bout of fantasy play in the three experimental conditions. Overall, it shows a higher
occurrence of fantasy themes than fantasy substitutions in all sessions. As demonstrated by a Wilcoxon rank test there was significant difference between fantasy themes and fantasy substitution in the physical session ($Z = -2.67, p < 0.05$), virtual Session 1 ($Z = -2.201, p < 0.05$) and virtual Session 2 ($Z = -2.668, p < 0.05$). Furthermore, there was a significant difference between the fantasy themes and the fantasy onomatopoeia in virtual Session 1 ($Z = -2.207, p < 0.05$), and virtual Session 2 ($Z = -2.429, p < 0.05$) but no difference between fantasy themes and fantasy onomatopoeia in the physical session ($Z = -0.632, p > 0.05$).

Table 31: The frequency and the mean for fantasy play characteristics per bout (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Themes</th>
<th></th>
<th>Substitution</th>
<th></th>
<th>Onomatopoeia</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Mean</td>
<td>Freq</td>
<td>Mean</td>
<td>Freq</td>
<td>Mean</td>
</tr>
<tr>
<td>Physical farm session (N=56)</td>
<td>185</td>
<td>3.3</td>
<td>31</td>
<td>0.6</td>
<td>135</td>
<td>2.4</td>
</tr>
<tr>
<td>Virtual farm (Session 1) (N=35)</td>
<td>87</td>
<td>2.5</td>
<td>17</td>
<td>0.5</td>
<td>6</td>
<td>0.2</td>
</tr>
<tr>
<td>Virtual farm (Session 2) (N=54)</td>
<td>182</td>
<td>3.4</td>
<td>20</td>
<td>0.4</td>
<td>27</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* N = number of fantasy bouts

In the physical session, 185 fantasy themes were produced by 9 dyads (five boy and four girl dyads). 87 fantasy themes were produced in virtual Session 1 by 6 dyads (three boy and three girl dyads) and 182 fantasy themes were produced in virtual Session 2 by 9 dyads (five boy and four girl dyads). Wilcoxon tests revealed that there was no difference in fantasy themes between the physical session and virtual Session 1 ($Z = -1.246, p > 0.05$), between the physical session and virtual Session 2 ($Z = -0.533, p > 0.05$), or between virtual Session 1 and virtual Session 2 ($Z = -1.724, p > 0.05$). Table 32 reports the frequency and the percentage of the objects used by children to enact fantasy themes in all play sessions. In the physical session, high fantasy themes were produced with animal objects. However, more fantasy themes in the virtual session were produced with other objects such as the play environment (the menu bar), the bottle and the trees. Animations from the play environment such as the rainy day and night time supports participant’s ideas in creating fantasy bouts.
Table 32: The frequency and the percentage of types of objects used by children in producing fantasy themes in play sessions (Study 3)

<table>
<thead>
<tr>
<th>Objects on The Farm</th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Percent</td>
<td>Freq</td>
</tr>
<tr>
<td>Human</td>
<td>36</td>
<td>19%</td>
<td>14</td>
</tr>
<tr>
<td>Animal</td>
<td>100</td>
<td>54%</td>
<td>29</td>
</tr>
<tr>
<td>Others</td>
<td>49</td>
<td>27%</td>
<td>44</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>100%</td>
<td>87</td>
</tr>
</tbody>
</table>

The tendency for children to produce fantasy onomatopoeia during all sessions was also observed; for instance, by mimicking the farm lady doll while bouncing the doll on the grass “La la la la la..”, producing a drinking sound while feeding the lamb or the foal with the baby bottle “Slurrppp..” and “aaaahhhh”, mimicking a horse galloping sound “geedeeuupp.. geedeeuupp”, producing a snoring sound “krrohh.. kroohhh” while pretending to sleep on the floor, mimicking the sound of the horse “neigghhh.. neigh”, the sound of the duck “quack.. quack” and the sound of the sheep “mbeekk.. mbeekk” while moving the animal. Overall, 135 fantasy onomatopoeia were produced by nine dyads (four boy and five girl dyads) in the physical session, but only 6 fantasy onomatopoeia were produced by four dyads (two boy and two girl dyads) in virtual Session 1, and 27 by six dyads (three boy and three girl dyads) in virtual Session 2. Infrequent onomatopoeia in the virtual setting may be due to the audio interference produced by the application. As demonstrated by Wilxocon rank tests, there was significant difference in fantasy onomatopoeia between the physical session and virtual Session 1 (Z = -2.668, p < 0.05) and between physical session and virtual Session 2 (Z= -2.558, p < 0.05), but no difference between virtual Session 1 and virtual Session 2.

Object substitution was captured less frequently during the evaluation sessions. In the physical session, 31 cases of fantasy substitutions were produced by five dyads (three boy and two girl dyads). In virtual Session 1, only 17 cases were produced by four dyads (two boy and two girl dyads) and 20 cases in virtual Session 2 by four dyads (two boy and two girl dyads). Wilxocon test revealed that there was no difference in fantasy substitution between the physical session and virtual Session 1 (Z = -0.68, p > 0.05), between physical session and virtual Session 2 (Z = -0.938, p > 0.05) or between virtual Session 1 and virtual Session 2 (Z = -0.271, p > 0.05). Evidence of the children transforming the objects during the play sessions was captured and reported in Table 33.
Table 33: The imaginative objects on The Farm transformed by children in play sessions (Study 3)

<table>
<thead>
<tr>
<th>Objects on The Farm</th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Human</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmer</td>
<td>Bad man</td>
<td>Daddy [x2]</td>
<td></td>
</tr>
<tr>
<td>Farmer's wife</td>
<td>Bad girl [x2]</td>
<td>Little girl [x3]</td>
<td>Bad witch [x4]</td>
</tr>
<tr>
<td>Guy</td>
<td>Guy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mummy</td>
<td>Mummy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little baby</td>
<td>Little baby</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Animal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td>Cow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamb</td>
<td>Female baby [x2]</td>
<td>Cow</td>
<td></td>
</tr>
<tr>
<td>Horses</td>
<td>Baby</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brother</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cow [x3]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mummy [x3]</td>
<td>Mama</td>
<td></td>
</tr>
<tr>
<td>Foal</td>
<td>Female baby [x6]</td>
<td>Female baby</td>
<td>Female baby [x4]</td>
</tr>
<tr>
<td>Ducks</td>
<td>Mummy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottle</td>
<td>Food</td>
<td>Coke</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Food [x3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tea</td>
<td></td>
</tr>
<tr>
<td>Hills</td>
<td>Door</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>House</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td>River with fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star</td>
<td></td>
<td></td>
<td>Spaceship [x2]</td>
</tr>
<tr>
<td>Mat</td>
<td></td>
<td>Pillow</td>
<td></td>
</tr>
</tbody>
</table>

[x ] indicates the number of times the imaginative objects were performed by the children.

From the observation, there was a variety of imaginative objects that were transformed with the objects provided in the Farm. Most of the transformations enacted by the children were based on the family roles such as daddy, mummy, brother and baby. However, there was still evidence of transforming the props as part of the fantasy, such as the star as the space ship and the mat as the pillow. Other examples from two different dyads who played in the physical and virtual sessions are transforming the edge of the hill into a shop (physical session) and a bottle of baby milk into a bottle of soft drink (virtual Session 1).
Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

[Molly (girl, 4 years) and Lola (girl, 4 years) play together with the physical farm]

Molly : Mummy horse wants to have a drink. (Bounces the mummy horse to the pond) But, there is no water left!
Lola : and then, the baby horse run.. and run.. and run to the shop.. to buy some water by herself (Bounces the baby horse on the path)
Molly : ( Watches Lola)
Lola : (Bounces the baby horse on the grass and stops next to the hill) and then, when she arrived at the shop.. she goes into the shop (Bounces the baby horse to the man human doll) Do you have any drinks? Oh yes! There are lot of drinks here. Thank you!

[Sue (girl, 4 years) and Kim (girl, 4 years) play together with the virtual farm Session 1]

Sue : (Drags the baby bottle to the grass)
Kim : Hmm... milk... (Points to the baby bottle)
Sue : No! It's Coke (Points to the baby bottle)

The evidence of using the plastic bottle in their fantasy play was observed in physical and virtual Session 1. For example, the children tended to feed the baby animal (the foal and the lamb) using the plastic bottle which contained the white liquid that most of them believed was milk in the physical session. This action was maybe related to their general knowledge about the connection of a baby with milk as the main source of food. However, in some cases, children tended to feed other animals and the human dolls with the bottle and mimicked the sound of drinking. In fact, some of the children tested, sucked and mimicked drinking the bottle by themselves. This action was also observed in virtual sessions where the children dragged the bottle to feed the foal and the lamb and also other animals, but there was no evidence of the children feeding the human dolls. Furthermore, the children tended to shake or play around with the bottle in the physical session, but there was no evidence of bottle manipulation in the virtual sessions as no rotation or other extra functions were provided.

In addition, the tendency of the children to feed the animals with the tree’s leaves was observed in both physical and virtual sessions. The following is an example from a dyad pretending a human doll is eating the tree’s leaves in virtual Session 2.

[Lola (girl, 4 years) and Molly (girl, 4 years) play together with the virtual farm]

Lola : and then.. there was a bad bad witch came. (Drags the lady human doll to the grass)
Molly : and the bad man.. (Drags the man human doll to the grass)
Lola : Smash! Smash! Smash! (Drags the lady human doll)
Molly : a tree came along.. (Drags the tree to the grass)
Lola : But then, he eat the tree.. yum yum yum.. (Drags the man human doll to the tree)
Molly : ( Watches Lola)
Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

From the observation, the way children moved the object while enacting their fantasy was different between physical and virtual sessions. For example, in the physical session, the children tended to bounce the object on the table showing the object’s movement. The following scenario is an example of a child imitating the voice of the duck while bouncing the duck on the table surface.

[Lina (girl, 4 years) and Rini (girl, 4 years) play together with the physical farm]

Lina : Quack! Quack! (Bounces the duck on the grass)
Rini : (Watches Lina)
Lina : Duck! Quack!! Quack!! He he.. (Looks at Rini)
Rini : He he.. (Gets the duck from Lina’s hand and puts it on the pond)

However, in virtual sessions, the children dragged the object in a straight line without wavering to show the horse running from location A to location B. The following is an example of children moving the horse on the tabletop.

[Molly (girl, 4 years) and Lola (girl, 4 years) play together with the virtual farm Session 2]

Molly : geedeeup .. geedeeupp.. (Drags the baby horse straight to the grass)
Lola : (Watches Lisa)
Molly : She needs the milk! (Drags the bottle straight to the baby horse)
Lola : and her mama came.. (Watches Lisa)
Molly : geedeeup .. geedeeupp.. mama’s here! (Drags the mummy horse and put it next to the baby horse)
Lola : Her daddy came long too! (Drags the daddy horse and puts it next to the mummy horse)
Molly : She wants to go.. to go somewhere else.. up in the sky.. (Drags the mummy horse straight to the hill) Oh dear! I’m in the wrong way!

6.4.3.2.1 Technology stimulated fantasy play

In this section the author will discuss the results on how the features of technology stimulated fantasy play. Based on the extended fantasy play analysis of selected excerpts where the fantasy play occurred, the evidence of the menu features provided by the application helped the children to generate their fantasy play bouts were observed. The children loved to use the menu to change from one play setting into another by pressing the menu button. Table 34 reports the frequency and the mean numbers of the settings used by the children in the virtual experimental conditions. The night setting was the most popular selection followed by day and rain.
Table 34: The frequency and the mean of the menu bar used per dyad to change the play environment in two play sessions (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Virtual Session 1 (N=10)</th>
<th>Virtual Session 2 (N=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Mean</td>
</tr>
<tr>
<td>Day</td>
<td>76</td>
<td>7.6</td>
</tr>
<tr>
<td>Night</td>
<td>98</td>
<td>9.8</td>
</tr>
<tr>
<td>Rain</td>
<td>74</td>
<td>7.4</td>
</tr>
<tr>
<td>Clear</td>
<td>30</td>
<td>3.0</td>
</tr>
<tr>
<td>Sound</td>
<td>59</td>
<td>5.9</td>
</tr>
<tr>
<td>Total</td>
<td>337</td>
<td></td>
</tr>
</tbody>
</table>

* N = number of dyads

The following scenario is an example from a dyad using the menu to change the play setting from a day-time setting into a night-time setting who pretending they needed to sleep during the night-time by laying down on the floor. Then the dyad changed the play setting into a rainy day and pretended they needed to use the umbrella to cover their heads from rains.

[Han (boy, 4 years) and Tim (boy, 4 years) play together with the virtual farm Session 1]

Tim : Night time.. (press the night button)
Han : Time to sleep (lay down on the floor)
Tim : OK. Lay down on the floor.. (Lies down on the floor next to Han and pretends sleeping)
Tim : Its raining!!.. (Stands up and presses rain button)
Han : Raining! We need umbrella! Its raining! (Covers his head with his hands)
Tim : Ha ha ha.. (Laughs while watches Han)

Another example from the same dyad changed the play setting from a day-time to night-time and pretended they needed to sleep during the night-time by laying on the floor and transformed the tabletop’s mat as their imaginative pillow. Then, one of the children pressed the music function and enjoyed the music by singing and dancing together.

[Han (boy, 4 years) and Tim (boy, 4 years) play together with the virtual farm Session 2]

Han : (Presses the night button)
Tim : Its time to sleep..
Han : Use this as your pillow (Points to the tabletop’s mat on the floor)
Tim : What pillow? Owh.. I think it’s comfortable. (Lies down on the floor and pretends sleeping)
Han : (Lies down on the floor next to Tim and pretends sleeping)
Han : Day time (Stand up and press the day button)
Tim : Now it’s music time! (Presses the music button)
Han & Tim: ee aa ee aa ooo (Han and Tim singing and dancing)
The animation provided by the application also helped the children to support their fantasy play. Based on the observation, after exploration of the application during the virtual Session 1, children discovered the animations that were available. The following is an example from a dyad using the animation of the animal to drink from the pond as part of their fantasy play.

[Joe (boy, 4 years) and Tom (boy, 4 years) play together with the virtual farm Session 2]

Joe : (Drags the mummy horse to the grass)
Tom : ( Watches Joe)
(Joe and Tom smile and look at the demonstrator)
Tom : Drink water... here.. (Asks Joe to drag the horse to the pond)
Joe : OK... geeedeupp .. geeedeupp.. (Drags the mummy horse to the pond)
(When the horse overlapped with the pond, a short animation of the horse drinking from the pond appeared on the screen)
Tom : Hmm.. Slurrpppp... So thirsty.. (Mimicking the horse drinking from the pond)

6.4.3.3 Social behaviours

Table 35 reports the number of dyads involved, the frequency and the average rate for social behaviours in three sessions. Significantly, more of the positive social behaviours were observed in all sessions. The average rate of positive social behaviours were significantly higher than negative social behaviours in the physical session ($Z = -2.395$, $p < 0.05$), in virtual Session 1 ($Z = -2.497$, $p < 0.05$) and in virtual Session 2 ($Z = -1.988$, $p < 0.05$). However, all other tests were non-significant.

Based on observations, more evidence of agreement was found in virtual Session 2 than in physical and virtual Session 1, mainly due to the agreement on placing the object on the play area. A higher frequency of disagreement was produced by dyads in virtual Session 2 than in virtual Session 1, mostly due to the disagreement on the use of menu to change the play setting. The results also show that the tendency of children to watch their partner during the play sessions was observed more frequently in the virtual sessions than in the physical session. As in Study 1, this tendency was mostly seen when they were preoccupied with the actions created by their partner, or were waiting in anticipation for their turn.

Asking for their turn was observed only in virtual Session 1 and virtual Session 2 (two boy dyads in Session 1 and one girl and one boy dyads in Session 2). Children showing the object to their partner was only observed in the physical session. The
tendency for children to contribute some ideas to their partner during all sessions was also observed; for instance, by suggesting actions to their partner, "Try go to the pond, the baby horse might be thirsty", "Let's get her dummy! (The bottle)", "Taste it. (Suggests his partner to taste the bottle)".

The results reported that a larger occurrence of children prevented their partner from getting an object when they played in virtual sessions than in the physical session. This finding was contradicted by the result from Study 1 as some of the children tended to group some of the objects together, which prevented their partner from getting the object from them. For example, some of the children gathered all horses or sheep in one spot to form a family group (consisting of a daddy, a mummy and a baby) and tried to protect the family group from being grabbed by their partner. However, the tendency for children trying to steal an object from their partner was observed more frequently in the physical session than in the virtual session, maybe because the children could easily grab it from the table or their partner's hands. The evidence of asking the partner not to disturb was observed only once in virtual Session 2 and helping the partner was noted once in virtual Session 1 and once in virtual Session 2.
Table 35: The number of dyads involved, the frequency and the average rate for social behaviours (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Ave. Rate (SD) *</td>
</tr>
<tr>
<td><strong>Positive behaviours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agreement</td>
<td>5</td>
<td>10</td>
<td>0.01 (0.10)</td>
</tr>
<tr>
<td>Ask for their turn</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Ask for object from partner</td>
<td>3</td>
<td>3</td>
<td>0.003 (0.005)</td>
</tr>
<tr>
<td>Ask partner’s opinion</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Ask partner to move object</td>
<td>3</td>
<td>3</td>
<td>0.003 (0.01)</td>
</tr>
<tr>
<td>Copy partner</td>
<td>4</td>
<td>8</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Help partner</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Offer object to partner</td>
<td>3</td>
<td>6</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Show object to partner</td>
<td>5</td>
<td>8</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Suggest an action</td>
<td>6</td>
<td>20</td>
<td>0.02 (0.04)</td>
</tr>
<tr>
<td>Watch partner</td>
<td>10</td>
<td>173</td>
<td>0.20 (0.05)</td>
</tr>
<tr>
<td><strong>Negative behaviours</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask partner not to disturb</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Ask partner to stop</td>
<td>2</td>
<td>5</td>
<td>0.01 (0.02)</td>
</tr>
<tr>
<td>Disagreement</td>
<td>6</td>
<td>33</td>
<td>0.06 (0.08)</td>
</tr>
<tr>
<td>Prevent partner get object</td>
<td>5</td>
<td>11</td>
<td>0.02 (0.04)</td>
</tr>
<tr>
<td>Refuse to play</td>
<td>2</td>
<td>3</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Steal object from partner</td>
<td>6</td>
<td>20</td>
<td>0.04 (0.04)</td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes.
6.4.3.4 Affective behaviours

Table 36 summarises the number of dyads involved, the frequency and the average rate for affective behaviours in the three sessions. In general, there was strong evidence of positive affective behaviours such as smiling and laughing in all sessions. The average rate of positive affective behaviours were significantly higher than negative affective behaviours in the physical session (Z = -1.988, p < 0.05), in virtual Session 1 (Z = -2.666, p < 0.05) and in virtual Session 2 (Z = -2.803, p < 0.05).

A high frequency of dancing was observed during the virtual Sessions 1 and Session 2 as the children reacted when they pressed the music button and listened to the music clip, but no evidence was found in physical session. However, Wilcoxon tests revealed that there was no difference between the average rate of dancing in virtual Session 1 and virtual Session 2. Furthermore, 13 instances of children singing whilst playing with the study materials were captured in the physical session. The evidence of singing increased in virtual Session 1 due to some of the children excitedly enjoying the music provided by the application, and they were experiencing the tabletop application for the first time. However, the evidence of singing decreased to only five cases in virtual Session 2, maybe due to the children not only focusing on the music function but also exploring other features of the application.

The evidence of children excitedly jumping on the spot during the play session was observed once in the physical session, when one of the girls responded excitedly to play with the toys. Furthermore, eight cases were noted in virtual Session 1 and six cases in virtual Session 2, mostly due to their response to the music. However, the tendency of children to be frustrated was observed more in the physical session than in virtual Sessions 1 and 2, one of the boys was frustrated when his partner stole the toys from his hand, and one girl was really frustrated when she several times tried to open and taste the milk from the bottle. In the virtual sessions, there was evidence of frustration due to the screen being reset by their partner, the partner stealing the objects by dragging them away, the partner changing a play environment that they liked (e.g. from day time to rainy day).

The evidence of sadness only occurred once, observed in virtual Session 2, and the evidence of anger was captured in virtual Session 1 when a girl’s partner stole the bottle and fed the sheep rather than doing what she wanted. In the physical session, some of the children looked bored at the end of the play session when they signalled to
stop the play and to go back to their class. No evidence of boredom was found in virtual Session 1 or Session 2.

### Table 36: The number of dyads involved, the frequency and the average rate for affective behaviours (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of dyads</strong></td>
<td>9</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td><strong>Freq</strong></td>
<td>142</td>
<td>326</td>
<td>238</td>
</tr>
<tr>
<td><strong>Ave. Rate (SD)</strong></td>
<td>0.26 (0.24)</td>
<td>0.67 (0.40)</td>
<td>0.39 (0.23)</td>
</tr>
</tbody>
</table>

#### Positive behaviours

- **Dance**: 0 0 6 6
- **Excited**: 5 11 5 11
- **Jump**: 1 1 3 8
- **Laugh**: 4 45 8 53
- **Sing**: 4 13 4 23
- **Smile**: 9 66 9 179
- **Surprised**: 4 6 5 11

#### Negative behaviours

- **Anger**: 0 0 1 1
- **Bored**: 4 8 0 0
- **Frustrated**: 2 11 4 6
- **Sad**: 0 0 0 0

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

6.4.3.5 Attention distribution

Table 37 reports the number of dyads involved, the frequency and the average rate for attention distribution in the three sessions. The most common type of attention distribution that occurred in all sessions was children looking at the demonstrator, mainly due to their being concerned about being observed by the researcher during the evaluations as in Study 1 and Study 2. However, Wilcoxon tests revealed that there was no difference between the average rate in the physical session and virtual Session.
1 (Z = -0.204, p > 0.05), between physical session and virtual Session 2 (Z = -0.459, p > 0.05) or between virtual Session 1 and virtual Session 2 (Z = -0.561, p > 0.05).

From the observation children tended to pause in their play, look around and continue their play after a while as in Study 1 and Study 2. The average rate was significantly higher in the physical session than in virtual Session 1 (Z = -2.547, p < 0.05) and there was also significant difference between virtual Session 1 and virtual Session 2 (Z = -2.09, p < 0.05). A high occurrence of children looking at the mat was observed in virtual Session 1 (N = 22) and in virtual Session 2 (N = 25), although Wilcoxon test revealed no difference between virtual Sessions 1 and 2 (Z = -0.210, p > 0.05).

Children also tended to walk away from the study materials during the evaluation sessions. In the physical condition, they tended to bring along the physical toys in their hands as in Study 1. In the virtual condition, the occurrence of children walking away from the tabletop was higher in virtual Session 2 than in virtual Session 1, maybe because they were busy exploring the application when they were exposed to the tabletop environment for the first time in virtual Session 1. However, a Wilcoxon test revealed that there was no difference between the average rate of children walking away from the study materials in virtual Session 1 and virtual Session 2 (Z = -0.845, p > 0.05).

The evidence of children playing with the wristband was also found in Study 1 and Study 2. However, Wilcoxon tests revealed that there was no difference between the average rate of playing with the wristband in the physical session and virtual Session 1 (Z = -1.014, p > 0.05), between the physical session and virtual Session 2 (Z = -1.352, p > 0.05) or between the virtual Session 1 and virtual Session 2 (Z = -0.314, p > 0.05). Two cases of children looking at the projector were observed during virtual Session 1 but there was no evidence of this in virtual Session 2. Furthermore, only two instances of noise distraction were observed (performed by one girl in the physical session and another girl in virtual Session 2).
Table 37: The number of dyads involved, the frequency and the average rate for attention distribution (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Ave. Rate (SD)*</td>
</tr>
<tr>
<td>Look around</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>123</td>
<td>1.71</td>
</tr>
<tr>
<td>Look at demonstrator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>133</td>
<td>1.93</td>
</tr>
<tr>
<td>Look at mat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Look at the projector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Noise distraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>Play with wristband</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>24</td>
<td>0.33</td>
</tr>
<tr>
<td>Walk away</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>29</td>
<td>0.31</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>310</td>
<td>4.30</td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

6.4.3.6 Interaction with the tabletop

Table 38 summarises the number of dyads involved, the frequency and the average rate of interaction with the tabletop in all sessions. In general, a higher occurrence of children tapping the table was observed in virtual Session 1 than in virtual Session 2, as they just loved to tap (to touch or select) the object, reflecting the confidence level of young children playing with the tabletop for their first time. However, the occurrence of tapping the tabletop was reduced in Session 2. They perhaps realised that they needed to drag instead of tap in order to move the object. However, according to Wilxocon test, there was no difference between the average rate of tapping the table in virtual Session 1 and virtual Session 2 (Z = -1.12, p > 0.05).

From the observation, all dyads in both sessions tended to use the hot spots area such as the pond, the path and the grass (virtual Session 1, N = 154; virtual Session 2, N = 280). The average rate was significantly higher in the virtual Session 2 than in virtual Session 1 (Z = -2.191, p < 0.05). A total of 126 occurrences were observed when the children dragged the object to the pond hotspot to trigger the animation in the virtual Session 1 and a total of 248 occurrences were observed in the virtual Session 2. A total of 15 cases were found when the children dragged the object to the grass hotspot.
in the virtual Session 1 and 21 cases were observed in virtual Session 2. There was
evidence of only 13 instances where children dragged the object to the path hotspot in
the virtual Session 1 and only 11 instances were captured in the virtual Session 2. The
frequent use of the pond hotspot to trigger animation may be due to the location of the
pond which was closer to the children and the object.

Children triggering the animation when objects overlapped was also observed in the
virtual Session 1 (N = 78) and in the virtual Session 2 (N = 69). A total of 22 cases of
animation were prompted when human dolls overlapped with the horses (a short
animation of a human riding a horse appeared on the path) in virtual Session 1 and 23
cases in the virtual Session 2. However, the occurrence of the baby animal (the foal or
the lamb) overlapped with the bottle (a short animation of the animal feeding from the
bottle) were observed 56 cases in the virtual Session 1 and 46 cases in the virtual
Session 2, maybe related to their general knowledge about the connection of milk as
the main source of food for baby animal.

More evidence of children putting their two hands on the table was observed in virtual
Session 2 than in virtual Session 1 and the demonstrator needed to remind them not to
do so. The tendency to hide the object was also observed, as in Study 2 when the
children dragged the object to the edge of the screen to make it disappear. A total of 12
cases were found in virtual Session 2, but only two cases in virtual Session 1. Furthermore, only one case of an object dragged around the screen was found in
virtual Session 1 and two cases in virtual Session 2, less in Study 2.

From the observations, eight cases of children dragging the same object were found in
virtual Session 1, but the occurrence was reduced to only two cases in virtual Session
2. In addition, two instances of children catching the animated object were observed
and only one in virtual Session 2 (e.g. the child tried to catch the animated ducks
swimming in the pond and to catch the animated horse running on the path).

In virtual sessions, the behaviour of wiping the table was observed whereby the
children wiped the table using their hands or fingers in order to touch or select the
object on the tabletop surface. A total of 17 cases of children wiping the tabletop were
observed in virtual Session 1 and the evidence increased in virtual Session 2 to 30
cases.
Table 38: The number of dyads involved, the frequency and the average rate for interaction with the tabletop (Study 3)

<table>
<thead>
<tr>
<th>Tabletop Action</th>
<th>Virtual Session 1</th>
<th></th>
<th>Virtual Session 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq.</td>
<td>Average rate (SD) *</td>
<td>No. of dyads</td>
</tr>
<tr>
<td>Catch animated object</td>
<td>2</td>
<td>2</td>
<td>0.03 (0.07)</td>
<td>1</td>
</tr>
<tr>
<td>Children drag the same object</td>
<td>3</td>
<td>8</td>
<td>0.11 (0.25)</td>
<td>1</td>
</tr>
<tr>
<td>Drag the object around the screen</td>
<td>1</td>
<td>1</td>
<td>0.02 (0.05)</td>
<td>2</td>
</tr>
<tr>
<td>Hide object from screen</td>
<td>2</td>
<td>2</td>
<td>0.01 (0.04)</td>
<td>3</td>
</tr>
<tr>
<td>Tap tabletop</td>
<td>3</td>
<td>90</td>
<td>1.28 (1.80)</td>
<td>8</td>
</tr>
<tr>
<td>Trigger animation in hot spot areas</td>
<td>10</td>
<td>154</td>
<td>2.20 (0.76)</td>
<td>10</td>
</tr>
<tr>
<td>Trigger animation when objects overlapped</td>
<td>10</td>
<td>78</td>
<td>1.06 (0.93)</td>
<td>10</td>
</tr>
<tr>
<td>Two hands on the table</td>
<td>7</td>
<td>25</td>
<td>0.35 (0.54)</td>
<td>7</td>
</tr>
<tr>
<td>Wipe the tabletop</td>
<td>5</td>
<td>17</td>
<td>0.22 (0.45)</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>297</strong></td>
<td><strong>4.24 (2.55)</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

6.4.3.7 Demonstrator involvement

Table 39 reports the number of dyads involved, the frequency and the average rate for demonstrator involvement in the three sessions. Demonstrator and children interaction in virtual Session 1 was relatively higher as the children were experiencing the tabletop application for the first time. As in Study 2, the demonstrator actively encouraged the children to explore the application and identified other extra features such as the function of the menu bar which could change the play environment, and the use of several hot spots which triggered animation. In virtual Session 2 the demonstrator let the children play by themselves and only interrupted when needed.

Very little evidence was noted of the demonstrator needing to encourage and remind participants in the physical session. This is in contrast to virtual Session 1, where there was a high occurrence of the demonstrator needing to adjust and remove participants’ hands and encourage them, but this was reduced in virtual Session 2. A Wilcoxon test revealed that there was a significant difference between the average rate of demonstrator encouragement between virtual Session 1 and virtual Session 2 ($Z = -2.191$, $p < 0.05$), maybe because the children were initially unfamiliar with the tabletop environment. However, the occurrence of the demonstrator needing to remind the children was higher in virtual Session 2.
Table 39: The number of dyads involved, the frequency and the average rate for demonstrator involvement (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Ave. Rate (SD) *</td>
</tr>
<tr>
<td>Adjust participant’s hand</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Encourage participant</td>
<td>3</td>
<td>9</td>
<td>0.11 (0.23)</td>
</tr>
<tr>
<td>Remind participant</td>
<td>1</td>
<td>2</td>
<td>0.03 (0.09)</td>
</tr>
<tr>
<td>Remove participant’s hand</td>
<td>0</td>
<td>0</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>11</td>
<td>0.14 (0.27)</td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

6.4.3.8 Other behaviours

Table 40 presents the number of dyads involved, the frequency and the average rate for other behaviours in the three sessions. In general, children produced various kinds of unexpected sounds which were not related to the fantasy play as in Study 1 and Study 2: for example, “cop! cop!”, “ssssss..”, “eeiiii..”, “eiiuuww”, “tutt tutt tootttt”, “weekkkk”, “wooww”, “auuchhh”, “zuuu”, “hackk”, “dadddaaaaa” and “cacacccddaaa”. More evidence of this was observed in the physical session than in virtual Session 1 and 2. However, Wilcoxon tests showed that there was no difference between the average rate of voice expression in the physical session and virtual Session 1 (Z = -0.7, p > 0.05), between physical session and virtual Session 2 (Z = -0.56, p > 0.05) or between virtual Session 1 and virtual Session 2 (Z = -0.56, p > 0.05).

The tendency of children to suck their fingers was also noted, as in Study 1. As demonstrated by a Wilcoxon test, there was no difference between the average rate of sucked fingers in the physical session and virtual Session 1 (Z = -1.826, p > 0.05) but there was a significant difference between physical session and virtual Session 2 (Z = -2.207, p < 0.05) or between virtual Session 1 and virtual Session 2 (Z = -1.997, p < 0.05).
Table 40: The number of dyads involved, the frequency and the average rate for other behaviours (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical</th>
<th>Virtual Session 1</th>
<th>Virtual Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of dyads</td>
<td>Freq</td>
<td>Ave. Rate (SD) *</td>
</tr>
<tr>
<td>Suck finger(s)</td>
<td>2</td>
<td>4</td>
<td>0.15 (0.43)</td>
</tr>
<tr>
<td>Voice expression</td>
<td>8</td>
<td>53</td>
<td>0.66 (0.81)</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>57</td>
<td>0.81 (0.80)</td>
</tr>
</tbody>
</table>

* Average rate = the mean of frequency of the behaviour of each dyad over their playtime in minutes

6.4.3.9 Preferences

At the end of the evaluation, children were asked to name their favourite play environment; the results are shown in Table 41. The participants were not influenced in any way by the researcher in making a specific decision. The feedback from the children revealed that 13 preferred to play with the virtual or tabletop environment and 6 preferred to play with the physical environment.

Table 41: Play environment preferences (Study 3)

<table>
<thead>
<tr>
<th></th>
<th>Physical farm</th>
<th>Virtual farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children preferences</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

6.5 Conclusion

This chapter has presented the performance of preschool children’s spontaneous fantasy play in the physical and in the virtual (tabletop) farm play environments. The study allowed children to play once in the physical condition and twice in the virtual conditions. Overall, children enjoyed playing in both conditions even though they were still new to the tabletop setting. But, no major interaction problems were found when they interacted with the tabletop in either of the virtual sessions (as compared to when children experienced serious interaction difficulties using the tabletop in Study 1); but the occurrence of children putting their hands on the tabletop was high. This could be due to the natural habit or common behaviour of preschool children (Berk, 2009; Cole, Cole & Lightfoot, 2005; Deloache, Eisenberg & Siegler, 2006). A simple puzzle task in the interview session helped the children especially the children who were shy, to be more confident in proceeding with the interview tasks.
The initial idea was derived from the play activity with a group of nursery children who helped the researcher to develop the concept of The Farm play setting. Then, a simple farm paper based prototype was exposed with a group of children for them to play and explore. Based on the observation, new additional ideas were suggested by the participants which helped the researcher to enhance the farm play setting by adding music, props and others. Later, the material of this study was tested in the pilot study sessions before being evaluated with a group of children recruited from a local nursery school. Therefore, the involvement of the children of the children helped the researcher to explore and understand the requirements for the users of this study. The benefit of gaining children’s inputs from the early stage of the study also gives insight to different views about the needs of the target users (Hana, Risden & Alexander, 1997).

Rich verbalisation was observed in both physical and virtual sessions within this study, increasing the chances of enacting fantasy bouts. Active conversations performed by male and female dyads were captured throughout most of the sessions. This may be due to the study was conducted in a private room, offering a quiet play environment for children to play without distraction. In contrast to the results in Study 1, there was little evidence of verbalisation being observed within the virtual condition, due to a greater focus on interaction difficulties with the tabletop by the children. However, the evidence of silent play was also observed during the play sessions.

The evidence of fantasy play bouts enacted by the children in this study demonstrated that the study materials allowed them to enact their fantasy play. This was proved by the occurrence of fantasy bouts in the physical session (N=56), in the virtual Session 1 (N=35) and in the virtual Session 2 (N=54), with the mean number of bouts per child being 2.9, 1.8 and 2.8 respectively. However, low occurrences of fantasy bouts in the virtual Session 1 may be due to the first experience when children play in the tabletop setting. However, these results suggest that the children were capable of producing spontaneous fantasy play using virtual objects as with the real objects. Analysis of the fantasy play revealed that there was no significant difference between the High and Low fantasy group performance in all sessions. The increment by Low fantasy group in the virtual Session 2 may be due to the children getting confident and enjoying interacting with the setting. In contrast with the results in Study 1 where the performance of High and Low fantasy groups in the virtual condition was very low as compared to the physical condition.
A high occurrence of fantasy themes was observed for both the physical (N=185) and virtual Session 2 (N=182), but only 87 occurrences were observed in the virtual Session 1. Complex stories were captured in both physical and virtual Session 2, which differed greatly from the results reported in Study 1, whereby the children tended to create simpler stories in the virtual session than in the physical session. Object substitution was rare in all sessions, as was supported by the results reported in the findings from Study 1. The tendency of the children to enact their fantasy relating to the family roles was also observed in the play sessions. This evidence supported the common roles created by children that were classified by Hughes (2010).

Very little evidence was observed for fantasy onomatopoeia in virtual Session 1 and 2 in comparison to the physical session, which is consistent with the results from Study 1. The evidence of the children loved to play with the menu to change the play setting into another setting that they preferred in the virtual conditions was also observed. Additionally, the evidence of the children’s use of the tabletop as an interactive device allowed them to create their fantasies while standing, sitting or laying on the floor. This enabled them to play in a more natural manner, encouraging them to generate further ideas and create additional and complex fantasy play scenarios.

Analysis of the social and affective behaviours revealed that positive was frequently higher than negative behaviour in all sessions. Furthermore, analysis of the demonstrator’s involvement showed that she needed to more frequently encourage the children to play in virtual Session 1 than in virtual Session 2. This is because the children were new to the tabletop environment and needed assistance in order to understand and become familiar with it. Very little assistance from the demonstrator was required to encourage the children to play in the physical session. The children demonstrated high evidence of smile, laugh and dance in both virtual sessions. These reactions may be due to the reaction to the animations and music provided by the application. The evidence of children singing the old McDonald song in the physical condition (N=13) while playing with the objects was observed. However, the occurrence in the virtual Session 1 (N=23) was nearly doubled from the physical condition because children loved to sing along with the music that was provided by the application. But, the low instances that were observed in virtual Session 2 (N=5) may have resulted because they spent more time with the menu function where they loved to change the setting of the play environment (N=375) and trigger the animation in the spot areas.
(N=280). Hence, there were evidence of fantasy play created by the children when the night time and rainy day animations were activated.

Overall, based on the observation when the children played with the physical and virtual farm play setting, there were a number of similarities and differences between the performances of preschool children’s spontaneous fantasy that can be drawn from this study. The focus of the comparison was between the physical session and virtual Session 2 because virtual Session 1 was the first interaction session for the children with the DT multi-touch interactive tabletop. They were given time to explore the application and become familiar with the new technology play environment, and were therefore more comfortable playing during the second session as they were familiar with both the setting and how the technology worked.

The following similarities were found between the physical and the virtual Session 2:

- **Object coordination.** From observations in both physical and virtual conditions, the objects were frequently reorganised on the play setting and coordinated with each other (e.g. sheep were located on the grass, ducks were allocated to the pond and the bottle was used to feed the baby lamb and foal). The results were similar with the findings when children played with the physical toys in Study 1.

- **Location of the object.** The objects that were located at the bottom area of the play setting (i.e. animal object in the physical condition; the menu bar and the animal objects in the virtual condition) allowed the children to access the object easily as the location of the object was closer to the children which supported by Rick, Harris, Marshall, Fleck, Yuill & Rogers (2009).

- **Imaginative objects.** Rare object substitution was performed in both physical and virtual settings since this age group developmental stage find difficult substituting objects (McLoyd, 1983).

- **Imaginative play roles.** The evidence of human and animal objects were played out as the family roles such as “mummy”, “daddy”, “brother” were highly observed in the physical and virtual setting, due to it is one that the children are the most familiar with (Hughes, 2010).

- **Silent play.** Children playing in silence was observed in both conditions which indirectly reduced by the possibility of producing fantasy play episodes.
Chapter 6: Study 2 – The Farm (Physical vs. Virtual)

The differences between the physical and virtual Session 2 were identified as follows:

- **Object selection.** In the virtual setting, the application only allows the children to select or move one object at one time but in the physical setting children could grab more than one object at one time. However, children preventing their partner from getting their object was observed to a higher degree in the physical condition because they wanted to control the object until they achieved what they desired.

- **Object movement.** The way that children move objects in the physical and virtual settings was different; they tended to bounce the object on the surface in order to show its movement in the physical condition, but, they tended to drag the object in a straight line from location A to location B in the virtual condition. This may be due to the difficulty of bouncing the virtual object by dragging and the application did not facilitate that specific function for children to use.

- **Object onomatopoeia.** There was very little evidence of object onomatopoeia was observed in virtual setting. This could be due to the children tending to imitate the sound representing only physical objects, but they did not show the same behaviour when playing in virtual Session 1 and 2. Furthermore, the audio interference generated by the application may reduce the possibility of the children producing the sound while enacting their fantasy in the virtual condition.

Also, some interesting findings about the creation of the fantasy play with virtual stimuli were:

- **Multimedia features.** The play setting in the virtual condition was more lively with the support of multimedia features provided by the application where children could choose their desired play setting to suit their fantasy themes which helped their play partner to understand their current play theme. For example, the children select the night button to change to a night-time setting and lay down on the floor pretending to sleep. Thus, it helped their play partner to understand the message and quickly join the pretend sleep on the floor. The sound performed by the animation also encouraged the children to copy and mimic the sound of the object which helped the children to increase the possibility of fantasy play and reduce silent play. Children also triggered the hot spots area to activate the animation such as the human riding horse running on
the path, the duck swimming in the pond or the sheep eating the grass on the field. In contrast in the physical condition, children needed to sing or produce the sound and make the object movement.

To summarise, the findings of this study provide the evidence of preschool children’s spontaneous fantasy play in the virtual setting. The next chapter will summaries, discuss and conclude the thesis.
Chapter 7: Conclusion

This final chapter concludes the research described in this thesis. It begins by summarising and discussing all the findings from the research activities and presents the research contributions. Furthermore, it points out the research limitations and makes recommendations for future work. Finally, design guidelines are provided for facilitating preschool children’s fantasy play in tabletop environments.
7.1 Introduction

Numerous scholars have agreed that fantasy play is important in children’s lives (Piaget, 1962; Vygostky, 1978; Singer, 1973; Smilansky, 1968). The evidence from empirical studies also suggests that tangible interfaces could stimulate fantasy play when children interact with technologically enhanced real toys (Casell & Ryokai, 2001). The research in this thesis was motivated by the lack of knowledge available in the HCI research community about the possibility for virtual objects to elicit fantasy play. The aim was to investigate the degree to which spontaneous fantasy play can be elicited in virtual environments implemented on a Mitsubishi DiamondTouch (DT) multi-user interactive tabletop device.

The main question of the thesis was, can virtual objects in the tabletop environment support and stimulate fantasy play of young children aged 3 and 4? In order to answer the main research question three empirical studies were performed with the following sub-research questions:

1. What are the similarities and differences in preschool children’s fantasy play in physical and virtual environments? (Chapters 4 & 6)
2. What exactly makes children engage spontaneously in fantasy play creation with virtual stimuli? (Chapters 5 & 6)
3. How can the multi-touch interactive tabletop support and encourage preschool children in enacting their fantasy play? (Chapters 4 & 5)

This chapter discusses the findings based on the three studies reported in the previous chapters and their contribution to knowledge in this subject by providing design guidelines in designing and facilitating tabletop environments for preschool’s fantasy play to aid HCI practitioners and designers.

7.2 Research Findings

The first empirical study was carried out with a group of preschool children recruited from the local nursery. The aim of the study was to explore the distinction between fantasy play in physical and virtual settings and the use of the tabletop as an interactive device for young children to enact their fantasy play. The findings demonstrated serious interaction difficulties experienced by the children whilst interacting with the tabletop which influenced the lack of the natural fantasy play creation as described in
Chapter 7: Conclusion

Chapter 4. Regardless of the usability problem in Study 1, evidence of fantasy play was still observed in the virtual condition; however, too few examples were recorded for significant comparison with the physical condition. The study also demonstrated that physical objects tended to foster the use of vocalisation in play, whereas the children did not perform the same actions in virtual settings.

There was very little evidence of object substitution and this was observed in both settings. Furthermore, the fantasy bouts enacted in the virtual setting involved a lower number of low structure objects than in the physical setting. Additionally, the findings from Study 1 revealed that the tendency of fantasy play stories created in the virtual condition were much simpler than those created in the physical condition. Poor interaction on the tabletop did not stop the children from enjoying it, as the evidence of smiling and laughing were observed, as well the duration of the play time performed by the children was not much different with the performance in the physical setting. Overall, very little verbalisation was captured during both settings and the noisy environment during the play session distracted the concentration of the children’s play performance. The study also demonstrated that children tended to spread the object randomly on the screen rather than play with the tree house.

The second empirical study was designed to eliminate the problems observed in Study 1 as described in Chapter 5. Overall, Study 2 solved the interaction problems in Study 1 and demonstrated that the tabletop can be operated by children as young as three, increasing the possibility of fantasy creation. The privacy of the study location offered a convenient environment for children to concentrate on the evaluation task without any distraction. The stools were removed and children were asked to stand on the mat in order to ensure better connectivity with the tabletop. Based on the observation, evidence of fantasy play was observed, which suggests that virtual stimuli can foster fantasy play whenever appropriate design allows children to play with them.

The study demonstrated that higher evidence of fantasy play was observed in Session 2 than in Session 1. Furthermore, High fantasy groups produced the evidence of fantasy play more than low fantasy groups. Most of the fantasy play creation was associated with High structure objects than Low structure objects. For example, the children tending to use High Structure objects to create most of their fantasy relating to real people (performance by the dolls). Additionally, there was no evidence of the use of low structure objects and this was demonstrated in object substitution and
onomatopoeia in both sessions. There was a high level of verbalisation observed in Study 2 as compared to Study 1. In general, children tended to use the magic wand in transforming the things into objects they desired as not all objects were visible on the screen whilst they playing with the application. However, the evidence of frustration was observed when the application did not respond as they wanted. Furthermore, the evidence of children looking at the projector during the play session was observed and prompted another safety issue that needs further attention.

Chapter 6 reported the third study by extending the findings from Chapters 4 and 5. This study investigated the children’s performance between the physical and virtual conditions; children were invited to play with real farm toys in the physical condition, and its virtual counterpart was implemented on the DT multi-touch interactive tabletop. In general, no major interaction difficulties were observed in either of the virtual sessions in Study 3. The children demonstrated rich verbalisation in all sessions, increasing the chances of fantasy play creation. The findings in Study 3 revealed strong evidence of fantasy bouts and more complex stories produced by the children were observed in both the physical and virtual Session 1; but low incidence of object substitution was captured in all sessions. Most of the fantasy play that was created by the children was related to the family roles. Low evidence of onomatopoeia was observed in the virtual setting as compared to the physical setting. The study demonstrated no significant difference between the performance of the High and Low fantasy group in all sessions. The findings also demonstrated that children tended to trigger the animation in the hot spots area and loved to use the menu to change the play setting. From the observations, this study highlighted a number of several similarities and differences between the physical and virtual conditions.

7.3 Discussion

7.3.1 Effects of tabletop setting

The major finding from Study 1 revealed that children faced difficulties when interacting with the tabletop, which disrupted their natural disposition towards the creation of fantasy play as described in Chapter 4. From the observations, children were very concentrated in moving objects (which were quite small for them to drag easily). The results showed that young children need more time to accurately select small objects, as observed in previous research (Donker & Reitsma, 2006; Hourcade, Bederson, Druin & Guimbretiere, 2004). The results also showed that children could increase and
sustain their attention on important information and ignore other distractions in order to complete a given task as demonstrated in previous research (Lopez, Menez & Hernandez-Guzman, 2005).

The findings in Study 2 solved the interaction problems observed in Study 1 and demonstrated that the tabletop can be operated by children as young as three, increasing the possibility of fantasy creation. Large sized objects and a simpler graphical environment helped the children to interact easily with the tabletop surface, which is consistent with the claims by Bruckman and Bandlow (2002) regarding the size of the objects and targets, which must be relatively large. The results also agreed that the touch screen technology is one of the easiest computer input devices (Shneiderman, 1991), and that the tabletop supports collaboration and offers more natural interaction styles (Apted, Kay, & Quigley, 2006; Dietz & Leigh, 2003; Piper, O'Brien, Morris, & Winograd, 2006).

The setting of the tabletop in Study 3 was improved based on problems observed in Studies 1 and 2. Therefore, this thesis demonstrated the tabletop setting was more appropriate and suitable for young children to interact with as reported in Study 3. The difference being that in Study 1, stools were provided by the researcher, whilst in Study 2 although the stools were removed there was evidence that children looking at the projector which distracted them from the game. Therefore, in Study 3 overcome the problem from Study 2; the positioning of the projector was altered, whereby the projector was projected directly facing towards the tabletop surface. The findings from the Studies 2 and 3 also revealed that the children did not mind removing their shoes on the mat while interacting with the tabletop, to ensure contact between the child and the mat was properly maintained. Both hands on the tabletop was still observed, may be due to the natural habit of young children (Berk, 2006; Cole, Cole & Lightfoot, 2005; Deloache, Eisenberg & Siegler, 2006).

7.3.2 Fantasy play and virtual stimuli

From the overall findings, this research has demonstrated that virtual stimuli can support and encourage the fantasy play of the preschool children. This study supports the claims from previous research on children’s play, which found that computer applications increase children’s creativity and contribution in developing the story in the game (Cappelletti, Gelmini, Pianesi, Rossi & Zancanaro, 2004; Cassell & Ryokai, 2001; Ryokai, Vaucelle & Cassell, 2003). Low evidence of fantasy play was observed
in Study 1, but significantly increased in Studies 2 and 3 as children had the opportunity to explore and become familiar with the application during the first session. This finding supported the claims that fantasy play can be increased by training (El'Konin, 1966; Smilansky, 1968; Fink, 1976; Saltz & Johnson, 1974). In general, the results of Studies 1 and 2 indicated that most of fantasy play themes performed by children were associated with high structure objects, and no evidence was found to prove that low structure objects improved fantasy play, consistent with the findings of McLoyd (1983).

Very little verbalisation was observed throughout Study 1, reducing the possibility of producing fantasy play bouts; this may be because of the noisy environment and interaction difficulties faced by children in the virtual condition, which also may be due to common behaviour of preschool children (McLoyd, 1983; Ackermann, 1996; Striano, Tomasello & Rochat, 2001). However, the level of verbalisation was increased in Studies 2 and 3, which indirectly increased the frequency of the fantasy play bouts and may be due to no major interaction difficulties with the tabletop and quite paly environment. From the observations, privacy of the study location offered a convenient environment for children to concentrate on the evaluation task without any distraction; which is consistent with Singer (1973) findings regarding the need for privacy, freedom from interference, acceptance of fantasy play activities and availability of fantasy materials. In Study 3, the research findings revealed that children tended to group and create family roles for their toys, such as mummy, daddy and baby, supporting the claims of Hughes (2010) about common roles that children created during their play.

Furthermore, there was evidence that children enjoyed the presence of music and animations. The results also agreed with Anderson and Levin (1976) findings that the presence of some visual and audio attributes increase the attention of young children. Analysis of the children's social and affective behavior demonstrated that positive behaviours were significantly higher than negative behaviours in all studies. Observations in Studies 2 and 3 also indicate that while using computers children interact with each other, negotiating access to the tabletop by taking turns, deciding or suggesting where to drag objects, and sharing the enjoyment of the action; as observed in previous findings of Plowman and Stephan (2005) in nurseries during their study of children interacting with computers. The demonstrator's involvement was reduced in the second session of the virtual setting, as the children were more capable in exploring and playing with the application on the tabletop; the demonstrator only
interrupted the children when needed. This supports the claim by Hanna, Risden and Alexander (1994) that the demonstrator need assist participants only when they are very lost or confused.

7.3.3 Advantages and disadvantages of virtual stimuli

The use of virtual objects in stimulating children’s fantasy play has both advantages and disadvantages. The first advantage is that virtual objects can be equipped with extra features such as animation and sound. Secondly, the presentation of the virtual object is adjustable (e.g. the size of the object can be reduced or enlarged, its colour can easily be changed, the object can be duplicated by the system). Finally, the virtual object can be saved, recorded or printed by the system as a copy of the activity.

The first disadvantage is that the virtual object cannot be picked up or held. Secondly, the perspective of the visual presentation of the virtual object on the tabletop may confuse the children, as it is a common behaviour in young children who may experience difficulties in understanding other people’s perspectives. Thirdly, the movement of the object on the tabletop is not straightforward and needs to be aligned, by translation or rotation. Significantly, the virtual object requires the use of a computer system and the device can be costly. Finally, a bigger tabletop surface is required to accommodate more objects; otherwise the screen will be overcrowded.

7.3.4 Physical vs. Virtual

The third study compared the performance of the children between the physical and virtual conditions; children were invited to play with real farm toys in the physical condition, and its virtual counterpart was implemented on the DT multi-touch interactive tabletop (refer to conclusion of Chapter 6). From observation, several similarities and differences between the physical and virtual Session 2 were highlighted. Overall, the similarities were found as follows:

**Object coordination.** The objects were frequently reorganised on the play setting and coordinated with each other (e.g. sheep were located on the grass, ducks were allocated to the pond and the bottle was used to feed the baby lamb and foal).

**Location of the object.** Children were easily accessing the objects that were located at the bottom area of the play setting (i.e. animal object in the physical condition; the
menu bar and the animal objects in the virtual condition) as the location of the object was closer to the children, which supported the findings reported by Rick, Harris, Marshall, Fleck, Yuill & Rogers (2009).

**Imaginative objects.** Rare object substitution was performed in both settings due to the children’s (this age group) difficulties in substituting the object (McLoyd, 1983).

**Imaginative play roles.** The family roles are those most likely created by the children in their play, perhaps due to the children are the most familiar with it (Hughes, 2010).

**Silent play.** The study demonstrated the evidence of silent play in both conditions which indirectly reduced by the possibility of producing fantasy play episodes. Hence, the moderate verbalisation is a common behaviour of preschool children (Ackerman 1996; McLoyd, 1983; Striano, Tomasello & Rochat, 2001).

The differences between the physical and virtual Session 2 were identified as follows:

**Object selection.** Children tended to grab more than one object at one time in the physical setting, but the application in the tabletop setting restricted the children so that they could only select or move one object at one time. However, the study demonstrated evidence of children preventing their partner from getting their object to a higher degree than in the physical condition because they wanted to control the object until they achieved what they desired.

**Object movement.** The children tended to bounce the object on the surface in order to show its movement in the physical condition. But, they tended to drag the object in a straight line from location A to location B in the virtual condition, due to the difficulty to bounce the virtual object by dragging the object on the surface. Furthermore, the application did not facilitate that specific function for children to use in their play.

**Object onomatopoeia.** The study demonstrated very little evidence of object onomatopoeia was observed in the virtual setting as compared to the physical setting, may be due to the audio interference generated by application.
7.3.5 Involving the children in design

This study demonstrates the continuous iteration process in designing the interactive fantasy play in a tabletop environment for preschool children, which involved various participants (i.e. children and teachers) in the design process to support and the benefits for the researcher in understanding and gaining the requirements of the target users (Bruckman & Bandlow, 2002; Hanna, Risden & Alexander, 1994; Scaife, Gould & Lewis, 1985; Rogers, Aldrich & Davies, 1997). The children and teachers were working closely with the researcher and were involved in contributing ideas from the beginning of brainstorming (formal and informal discussion sessions), which later the researcher transformed all the collected ideas into the prototypes. However, the problem with gaining information from the children was when the children were shy in sharing their thoughts. But a possible solution is to conduct the survey session with a group of children playing together with the materials. This may result the children feeling more comfortable to interact with the task and contribute their ideas.

The series of pilot studies were also conducted in the study to help the researcher to ensure the materials were ready for evaluation and testing before the actual study session with the nursery children. However, sometimes the children show behaviour that is very difficult for adults to anticipate, whereby this study revealed unexpected findings (i.e. interaction difficulties as reported in Study 1) from the participants during the evaluation sessions which was not detected during the pilot study. Later, the problems that occurred in this research (as reported in Studies 1 & 2) were resolved, by redesigning the prototype and tested with the nursery children as described in Study 3. Overall, this study not only involved the children as the user, but also as the informant and tester as suggested by Druin (2002).

7.4 Research Contributions

The contributions of the thesis are:

- Highlighting the interaction difficulties experienced by the children and underlining the behaviours of how young children perform their play whilst interacting with the multi-touch interactive tabletop.

- Demonstrating the evidence of children elicit fantasy play in both physical and virtual environments and how virtual environments can support and stimulate the fantasy play of preschool children.
- Highlighting similarities and differences between the physical and virtual conditions, offering a better understanding of how preschool children performed their fantasy play in both environments.

- Providing the requirements for designing and facilitating preschool children’s fantasy play in tabletop environments.

In general, the findings of this thesis have contributed new knowledge to the HCI community by reporting valuable results via empirical investigations towards understanding the possibility of the fantasy play creation in physical and virtual settings and suggesting how to improve the design of the play setting with virtual stimuli.

### 7.5 Limitations and Future Work

This thesis was concentrated on the creation of fantasy play supported by virtual stimuli on the tabletop environment. The evaluation sessions were limited to dyads of children, but the performance of groups of children or of a single child may offer insightful information. The research did not focus on gender differences, and it would be interesting to compare how gender differences or mixed genders affect performance of fantasy play in the tabletop environment.

The number of volunteer participants in this study was quite small. Due to time and resource limitations, the research was only conducted at one nursery class in each of the evaluation studies. These studies could be further replicated by expanding the number of participants from different nursery schools and recruiting older children (i.e. 5-7’s age group) in order to explore the preschool children or other age group’s fantasy play performance.

This thesis indicated different type of play observed such as solitary, onlooker and parallel play. But we did not focus on the various types of play systematically. However, future work could focus on the investigating the performance levels of the children behaviour in different types of play environment whilst enacting their fantasy play.

The tabletop application only allowed children to drag and drop the virtual objects on the tabletop surface, and the application could be enhanced by providing gesture
interaction styles. Having more interaction functions would provide more flexibility for children to handle the virtual objects on the tabletop surface.

The graphical design in this thesis only focused on 2D representation. Further research can expand this by improving the design from 2D to 3D representation within the virtual tabletop environment. This will allow other researchers to explore whether the 3D environment can stimulate fantasy play more than 2D representations.

### 7.6 Design guidelines

Interestingly, there was no previous study of children as young as three interacting with the DT multi-touch interactive tabletop. Therefore, this thesis contributes conclusions about the performance and behaviour of young children using the DT multi-touch interactive tabletop as the interaction device as described in Studies 1 - 3. The following design guidelines are proposed based on the research findings within this thesis which are useful for researchers and software designers in designing and facilitating tabletop environments for preschool’s fantasy play.

**Tabletop setting (DiamondTouch multi-touch interactive tabletop)**

To maximise the success of the tabletop interaction, the setting of the tabletop is suggested as follows:

- The ideal height of the tabletop for preschool children is about the height of the coffee table (45cm height from the floor), which allows children to reach all areas of the tabletop.
- Mount the projector (122cm from the table to the projector) above the children’s height and make it unreachable by the children, and also away from children’s head to avoid the children directly looking at the projector’s light.
- Secure the tabletop properly to the tabletop frame for safety purposes.
- Locate the mat on the floor to maintain the signal connection from the participants to the DiamondTouch multi-touch interactive tabletop.
- Ask the children to stand on the mat and take off their shoes before playing for better connectivity with the DiamondTouch multi-touch interactive tabletop.
- Avoid providing stools as children tend to move and rest their feet while sitting on the chair and do not place their feet properly in required position.
Chapter 7: Conclusion

- If the children begin to move away from the tabletop’s mat, they should be gently reminded to maintain their connectivity with the mat.

Virtual setting

- Avoid using sized of small objects as the children may face difficulties to make the object stick to their finger when dragging and moving the object. Chapter 4 highlighted different kinds of hand gestures performed by children in order to move the object such as using their thumb, middle finger, palm, two fingers, all fingers and even little finger.
- Locate the objects closer to the user as the smaller children may experience difficulty in reaching objects which were far from their position on the tabletop.
- Design the application without a predefined task, so the children can spontaneously explore the materials freely whilst playing.
- Set the objects clearly visible on the screen for easy access and object handling.
- Provide several play settings or backgrounds. Therefore, children can change the play environment as they desire to support and encourage more creation of themes and story for their play.
- Design the application that provides a clear view and easy access from the location and position of the participants because young children have difficulties in understanding different points of view. Therefore, by asking the children to stand next to each other they can share the same view as their play partner.
- Provide high and low structure objects for children to use in supporting their play.
- Provide animations and sounds that are associated with the object, suitable music which is relevant to the play setting in order to support children’s play and create a fun play environment. Additional functions such as hot spots area can also help children to enhance the creation of their play.
- Provide reset or clear functions to reset the screen and set all objects back to their original position, so the children have the choice to start or continue their story with new clear screen.
- Arrange a simple training activity or a demo session for the children to learn and become familiar with the virtual setting.
- Allow the children to use the game application more than once, as the first session will be necessary for exploring and understanding the motherhood game.
Child behaviours whilst interacting with the tabletop

- If possible, encourage the children to use only one hand while interacting with the tabletop to avoid dragging errors as the children tended to put both hands and rest their forearm or other fingers on the tabletop surface.
- The children should be gently reminded not to drag the same object at the same time, or select two objects at the same time as it will cause dragging errors.
- Children tend to tap quickly on the tabletop surface in order to select the object. They should be gently reminded to select the object properly to avoid disappointment.
- For children who are struggling when attempting to drag and point to the object with only one finger, suggest using two or more fingers for easy object handling.
- Some of the children applied too much pressure when selecting and pressing the object, which produced a squeaky sound from the table. Children should be gently reminded not to press the object too hard and encourage them to be more relaxed whilst dragging the object on the tabletop surface.

Further guidelines to setup an evaluation with young children are as follows:

Experimental setting and procedure

- Arrange the session in a quiet room to help the children to be more focused on the tasks.
- Locate and face the equipment away from the children (i.e demonstrator’s PC, camera) to avoid any distraction.
- Use two cameras to capture the scene from different viewpoints to avoid disappointment of losing images when the camera was blocked by the children and screen capture to record activities on the tabletop screen during the experiment session.
- Provide a pair of coloured paper wristbands to each child for easy recognition.
- If the study requires the use of more than one piece of equipment, place the different types of equipment next to each other but ensure that only one can be seen at any one time.
- Let the children work with partners as the shyer children may be uncomfortable being alone with the evaluator (Hana, Risden & Alexander, 1997); Ask the class
teacher to group the children based on existing friendships to encourage collaborative play.

### 7.7 Conclusion

This thesis presents three evaluation studies with preschool children for eliciting fantasy play in the tabletop environment. It has increased understanding about the way children enacting their fantasy play in both physical and virtual conditions, and how the virtual stimuli support and encourage the fantasy play of preschool children. The thesis demonstrated that virtual stimuli could stimulate appropriate preschool children’s fantasy play, where interaction design permit children to engage with them. The investigation has also demonstrated that children as young as three can create fantasy play using the DT multi-touch interactive tabletop. However, successful interaction requires larger targets and a simple graphical environment, in which children stand on the mat in bare feet to ensure that the connection between the child and the mat is properly maintained. This study also offers first-hand experience of working with young children, leading to a better understanding of the potential of virtual stimuli in supporting fantasy play. Furthermore, the author provides design guidelines for HCI researchers and software designers based on the research findings.
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‘My world(s)’: a tabletop environment to support fantasy play for kindergarten

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ABSTRACT
This research aims to design My World(s) a tabletop application for kindergarten children’s (age 3 to 5 year-old). My world(s) will provide an interactive tabletop environment to support individual or peer-to-peer fantasy play and offer young children the possibility to create and enact their fantasies in a digital context. The research will be based on literature review, field studies (observations of young children activities in ecological settings) and interviews with nursery teachers and parents. A prototype of My world(s) tabletop application will be developed based on the data gathered and it will be evaluated empirically.

Keywords
Kindergarten children, fantasy play, tabletop environment

INTRODUCTION
This PhD project aims to design My World(s) a tabletop application for kindergarten children’s (age 3 to 5 year-old). My world(s) is intended to provide an interactive tabletop environment to support individual or peer-to-peer fantasy play offering young children the possibility to create and enact their fantasies.

Fantasy play is a recreational activity where children move from real into imaginary worlds. It can also be referred to as make believe, imaginative, pretend or symbolic play. Tabletop is a new form of human-computer interaction, where a tabletop is used as input/output device. Tabletop can be used to create collaborative environments in which virtual objects can be displayed on a table surface through projection and can be manipulated touching the surface [1, 2]. Tabletop also gives the possibility of using multiple cursors simultaneously.

The basic question addressed by the project regards the possibility of supporting fantasy play within a digital environment, as fantasy play traditionally is enacted on physical objects or imaginative objects. Another important challenge is to allow the children to be the author of their fantasies and not the receiver of pre-set stories. A further challenge regards the adaptation of methods and techniques developed for interactive design for children (IDC) to the sample in consideration, who is still largely unexplored. The project is also intended to analyse the feasibility of tabletop as an interaction tool for young children.

The research will be based on literature review, field studies (observations of young children in ecological settings) and interviews with nursery teachers and parents. The literature review will focus on developmental psychology, educational studies, HCI and IS. User-centred design will be applied to build and evaluate My world(s). The paper is structured in 3 sections. Section 1 provides a summary of relevant literature. Section 2 provides the research motivations. Section 3 provides an overview of the conceptual design of My world(s) and of the design methodology.

LITERATURE REVIEW
Kindergarten children
Children have unique characteristics, needs and desires which differ from those of adults and between different age groups [3]. Children move through stages of development as they grow up and learn from their environment through experiences. The rate of development varies from one child to another and from one age group to another. Piaget’s divides intellectual development into 4 major periods [4]:

• Sensorimotor (births to 2 years old)
• Preoperational (2 to 7 years old)
• Concrete operational (7 to 11 years old)
• Formal operational (11 years old and above)

IDC is a complex field as it encompasses a very large variation in user. This project will concentrate on kindergarten children (preoperational stage). In this stage, Piaget’s describes children as imperfect in the course of their actions, as they tend to do many errors, use simple words to describe what they see or experience, observe things and construct mental symbols through imitation [4]. They only can hold one memory at a time, cannot understand situation from another person’s point of view, face difficulty with abstractions and are developing skills of...
reading and writing [5]. It is also a time in which children progressively obtain systematic and logical thinking [6]. Children begin to develop their muscles and movement skills since they are born. As children grow, their muscles become stronger and more developed. That is why the motor skills of young children are said to be less developed than those of older children and adults.

**Play**

Play is an integral part of children’s lives and development [4, 7, 8]. It is not a distraction: children learn to play and play to learn by manipulating objects in their world [3]. As mentioned by Verenikina et al [8], “Play is not only an enjoyable and spontaneous activity of young children but it also contributes significantly to children’s psychological development”. Developmental psychologists agree that playing is more than just having fun [9]. While playing, children develop their understanding of themselves and others, increase their ability to communicate with peers and adults, and explore their knowledge of the real world. Through play, children act out the world inside them and share it with others.

Children play in variety of ways and tempo, from calm to active activities [10]. Stages and level of play among children are also different. Normally, their play becomes more complicated when they grow older as they learn more through experience [4, 8]. There are 4 different types of play namely [11]: (a) Locomotor play, (b) Language play, (c) Object play, (d) Fantasy play.

**Locomotor play** can be referred to as playing with physical actions or bodily movements often without objects. It includes actions such as kicking legs, throwing, crawling and waving arms for babies, and rough-and-tumble play such as fighting, chasing, jumping, climbing and running for older children. Normally play that involves physical contacts, such as chasing and wrestling, is signalled by smiling and laughter [11]. **Language play** involves playing with words and sound (conversations, rhymes and repeating patterns) [11]. It begins very early and sometimes goes unnoticed, such as babbling or the repetition of certain noises. In language play, children find out the special ways by which language can be combined and they can turn words into playthings. As children grow up, they become more skilled at using language and they use it in further approaches for superior effect [11]. **Object play** can be described as manipulation of objects while playing. Children up to 1 year normally perform simple actions such as mouthing, shaking, pushing and banging with one or two objects while older children are more engaged in constructive play, such as creating things from objects and use objects to support their fantasy play. **Fantasy play**, sometimes referred to as pretend or symbolic play, is make-believe play where objects and actions are transformed to suit an imaginary setting [12].

**Fantasy play**

Children use imagination in fantasy play where they move from real into imaginary world. Piaget labels this activity as “symbolic play” [8]. This form of play affords children the opportunity to experiment with different events, experiences and possibilities in their lives. Examples of fantasy play are: making a cake from sand, wearing a white jacket to be a doctor or constructing an imaginary house from an empty box. Children begin to understand how things work and what things are for through imitating things around them.

Early forms of fantasy play can be seen from about 12-15 months [11]. Most of early fantasy plays rely on actual objects such, as cups and spoons to feed dolls. Later on, children start using objects to represent something else, e.g., a wooden block as a ‘cake’ or a stick as a ‘gun’. During early symbolic play, children normally use themselves as agent [6]. For instance, 18 months old children pretend to eat from a bowl together with enthusiastic eating sounds or they pretend to drink from an empty cup. By around age of 2, children are able to shift and move from using themselves as agents to using toys as agents [6]. In his extensive study on how children shift the role of agent from themselves to toys, Piaget describes his experience with his daughter Jacqueline. During earliest pretend play, Jacqueline pretended to sleep on a cloth and a month or so later she acted the same actions to her teddy bear [11].

The elements of pretend play differ from one child to the other and according to their level of maturity [6, 9]. Piaget divided symbolic play into 2 main stages. Stage 1 consists of children up to 4 years old and stage 2 consists of children from 4 to 7 years old. Stage 1 is articulated into 3 sub-stages. During sub-stage 1, children project familiar symbolic actions to new objects. For example, Jacqueline at 19 months ordered her toy dog to cry and she imitated the sound of cry. A few days later she ordered her hat to cry. From the example, it emerges that young children replicate their own actions in their pretend play. In sub-stage 2, children start using imagination and imitation. For instance, Jacqueline at 22 months rubbed the floor with seashell and then with the cardboard lid. She had previously observed the cleaner cleaning the floor. In sub-stage 3, children pretend play involves combination of complex symbols. Piaget illustrated that Jacqueline at just over 2 years old, held a brush over her head and imagined the brush to be an umbrella. In the second stage (age 4 to 7 year-old), symbolic play becomes more orderly and an exact imitation of reality is often enacted.

Up to age 7, pretend play grows from an individual form of play to a more complicated social activity. Initially, children’s pretend play does not involve other children. For instance, early pretend play is usually done solo or maybe with a parent or carer as cooperating helper or supporter. As the child grows, they begin to notice other children’s
pretend play and imitate it. At about age 4, well
developing children may have rich imaginary play and
tends to take on a more social approach, enacting
complex and interactive imitation of reality [6]. At this
stage, they start assigning roles to peers: "I'll be the
doctor and you'll be the patient". As the complexity
increases, kids may spend more time to set up the
plan and assigning roles than in the actual play.

Interaction design and children
Today's children grow up in a computer technologically
era where it is expected that they become "masters" of
interactive devices at early ages [13]. Adults and
children often refer to children's interactions with the
computer as "playing with the computer" [14]. Children
are attracted to computer technology and want to
"play" with it [10, 15].

Children love to use the computer with minimal
intervention from adults [16]. Children like being in
control as they can challenge themselves and explore
the world surrounding them [3]. Observation at a
nursery have indicated that while using computers,
children interact with others negotiating access to
computer by taking turns, deciding where to click and
sharing the enjoyment of the action [14].

However, due to motor skills limitations, young
children face difficulties while interacting with
computers. For instance, pointing with a mouse to
small objects could require more accuracy than
children are capable of. Previous research has shown
that young children age 4 - 7 years old needed longer
time to aim and click accurately at small objects [17,
18]. Therefore, objects and targets must be relatively
large [5]. Uses of the keyboard also need to be
avoided. According to Inkpen [19], software specifically
designed for children is more effective and children
performed better by point-and-click rather than drag-
and-drop interaction.

Usability is very important when designing for children.
Poor usability, combined with children's lack of
patience when dealing with complex situations, induce
children to leave the application. Usability is a
prerequisite for learning and fun [5]. Since young
children are different from adults and older children,
understanding their specific requirements is
instrumental to successful software.

RESEARCH MOTIVATION
Despite a growing literature of research and practice in
the field of IDC, kindergarten children have received
little attention so far, yet they are becoming an
important target for the IT industry. Little is known
about this particular user sample and little research
has addressed the use of tabletop with children. In this
research we intend to explore the design space of an
interactive tabletop environment to support
autonomous fantasy play by kindergarten children.
The investigation will be supported by a strict user-
centred design approach.

RESEARCH APPROACH
My world(s): conceptual design
My world(s) offers young children the possibility to
engage in fantasy play individually or with their peers
in a tabletop environment. The DiamondTouch table
will be used as interactive device. DiamondTouch is a
front-projected table connected to a computer and a
projector. It allows users to simply touch the table
surface to access computer-based materials. DiamondTouch supports small group collaboration by
supporting multi-user interaction with the display
simultaneously. Each user has a separate receiver.
Array of antennas embedded in the touch surface
transmit signals from the touch surface through the
user's body to the receiver in order to coordinate
inputs from multiple users.

Preliminary ideas on My World design are illustrated in
the following scenario:

Thomas and Andrew decide to play with My world(s).
The system is displaying a number of environmental
contexts (e.g., desert, city, mountain setting, etc).
Thomas selects the "city" picture by touching the
object using his finger on the table surface. The
system dynamically changes to "city" environment,
displaying the city map. Andrew decides to explore
inside the hospital by touching on the "hospital" object.
Then, their fantasy play begins where they can start
enacting and creating their story based on the
"hospital" environment. For example, Thomas acts to
be a doctor and pretends to treat patient by using the
virtual hospital equipments. Andrew acts as a doctor
assistant, helps the doctor by preparing the
equipments. The virtual objects in the system
represent the real function and appearance in the real
world where it helps the fantasy play closed to real.

My world(s) can have several advantages. Firstly,
children can enact their fantasies in their own way
rather than using the fantasy world that has been set
by the software designer. It also offers the possibility
of 'saving fantasies and imaginary world' and sharing
with others, as well as of incorporating real objects and
virtual objects.

Methodology
This research will involve follow the UCD process
including: (1) Analysis phase (2) Design phase (3)
Evaluation phase [20]. The analysis phase will be
based on literature review on socio-cognitive
development, play and IDC. User requirements will
also be gathered through ethnography studies in
kindergartens. Interview with nursery teachers and
parents will also be conducted. All data will be
recorded in notes and audio format for analysis
purposes. Analysis phase is expected to be completed
by the end of first year.

In the design phase low fidelity prototypes will be
developed (with several types of interactive
metaphors) will be tested with children and adults.
They will be tested then by
enhance into high fidelity prototype, which will be evaluated with kindergarten children in usability testing. Results can either suggest to proceed to the next phase of the design or to reorient the research to another analysis phase and so starting a new cycle. This phase is expected to be conducted in the second year of the research.

At evaluation phase, usability testing will be conducted again with a sample of kindergarten children. Diamond table will be used as input device during the usability testing. Thus, the result of this phase will lead to the final prototype output or to be iterated again to analysis or design phase. At the end of the research cycle, the outcome of the research will be a prototype of interactive fantasy play in a tabletop environment for kindergarten children and deep understanding on kindergarten children’s needs and capabilities in their play.

ACKNOWLEDGMENTS
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REFERENCES
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Little fingers on the tabletop: A usability evaluation in the Kindergarten

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Abstract

This paper presents selected results from an experimental study designed to compare fantasy play in a virtual and physical setting. Twenty-two children (aged 3 and 4) played in same-sex dyads with a real wooden tree house and its virtual implementation on a DiamondTouch tabletop. The study evinced several problems in the interaction with the tabletop as children often struggled to drag the objects displayed on the surface. An error analysis is presented and results are used to propose guidelines for improving the use of DiamondTouch tabletops by young children.

1 Introduction

A large number of computer applications are available on the market offering a wide choice for children to play with. Children enjoy playing with computers, but current products do not necessarily encourage them to use their imagination. Yet, fantasy play is a fundamental component of children’s development and has been found to have a number of social and cognitive benefits [1]. Fantasy play is a spontaneous activity where children give new meanings to objects while playing [1, 2]. For instance, a spoon can be transformed in a sword, or a brush can become an umbrella. Similarly, children can attribute social roles to themselves and others, as in ‘I am going to be the doctor’.

A recent study suggested that technology has the potential to stimulate fantasy play when virtual and physical stimuli are combined [3]. Yet, little research has addressed how virtual objects relate to fantasy-play. Our research focuses on kindergarten children (3-4 years old), as this is the earliest stage when they start sharing and coordinating fantasies with peers. This user group is largely unexplored in interaction design, yet its importance has increased in recent years due to the diffusion of computers in houses and nurseries.

In our research we use the DiamondTouch table as interaction device, as it has the advantage of supporting collaboration, providing multiple cursors and dealing with simultaneous inputs. It also provides a large space for children to play with and an intuitive interaction style [4]. In this paper, we report some interaction issues with the use of the tabletop observed during user-research. We also propose guidelines to make the tabletop more accessible to young children.

2 Study

The experiment was designed to understand the similarities and differences between physical and virtual objects to elicit fantasy play in young children.

2.1 Participant and design

A total of 25 children (14 boys and 11 girls) were recruited from the Webster Primary School in Manchester. All children were between 3 and 4 years old (mean=44 months, SD=4.3 months). Parental permission was obtained for each child before participation. On the day of the study, one girl and one boy refused to participate and one boy was absent. Thus, the sample consisted of 6 dyads of boys and 5 dyads of girls. One of the girls was a special needs child. The nursery teacher selected the dyads by matching children based on their friendship.

The experiment was based on a within-subjects design. The children were asked to play in both physical and virtual environments in order to compare their performances in both conditions. In the physical environment, children played with a wooden tree house and a set of physical objects. In the virtual environment, a virtual tree house and virtual objects were displayed on the tabletop.

2.2 Apparatus

The wooden tree house was designed and built to provide a gender-neutral alternative to the Rochat's
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dollhouse [2]. It consisted of four open plan rooms attached to a tree base (Figure 1). The tree house was located on a coffee table (60cm x 60cm), together with a set of wooden objects. Following the experimental procedure proposed by [2, 5] these objects could be either realistic (e.g., dolls and suitable props for the house, such as a chair, and a TV) or non-realistic (small rocks, wooden sticks of different sizes and a set of wooden constructions).

Figure 1: The physical tree house

In the virtual environment, the children played with a virtual tree house, which closely resembled the physical one in appearance (Figure 2). The tree house was implemented in Macromedia Flash and displayed on the tabletop screen (60cm x 76cm).

Figure 2: The virtual tree house

The tree house provided the same set of realistic and non-realistic objects as in the physical setting, but it also included some extra multimedia features, such as a few animations and sounds. For instance, the stone could be thrown and would bounce around the screen, the light switched on every time it was moved and the dolls waved or danced when moved. Objects could be moved around the space by dragging them with a finger.

In order to ensure maximum safety for the special population tested in this study, we had to build a robust iron frame moving the projector high, well above the children reach. The frame was also used to connect the Diamond Touch tabletop to a little coffee table. The mats were located on the floor and two children’s chairs were provided (Figure 3). It was initially decided to invite the children to sit, to ensure that they would not move around the table thus leaving the mat.

Figure 3: Tabletop setting

The virtual tree house was tested with a sample of 4 children, from 2 and half years old to 5 years old (accompanied by their parents) in the HCI lab. No particular problems with the interaction emerged in the pilot studies and even the youngest child was capable of moving objects on the tabletop. Perhaps due to the small sample size involved, not all children being in the target age group and the lab environment influencing children to control their behaviour more, none of the problems experienced in the experiment were observed in the pilot study.

2.3 Procedure

The study was conducted during school time in a corner of a large schoolroom where dyads were transferred from their nursery class to the study location. The physical tree house and the tabletop were located next to each other. The order of presentation was counterbalanced among dyads. Privacy was ensured by a set of screens, yet the environment was often quite noisy. Two experimenters supervised the study: one interacted with the children, while the other operated the equipment. The children were already familiar with the main experimenter as he spent a few days in the kindergarten before the study.

At the beginning of the study, the experimenter explained the safety and important information such as the exit door and location of the toilet. Children had distinctive coloured paper wristbands to differentiate who was touching what. Each dyad played in the two different conditions for about 15 minutes each.

In the physical setting environment, children were given an introduction about the task by the experimenter before the dyad started their play session. In the virtual setting environment, there was a simple training phase in which seven little balls were displayed on the screen and children were invited to drag them inside a box (Figure 4). Each ball produced a different sound when successfully moved into the box. This phase lasted the maximum of 6 minutes and ended earlier when there were signs of lost interest among the children. During the training phase, particular emphasis was given to inform the children of the need to keep both feet on the mat, touch the table with only one hand at the time, and control the body posture to avoid blocking the image projected on the table.
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Figure 4: Virtual training phase

After the training phase, a cartoon spider introduced the virtual tree house: “Hello, my name is dingle dangle. Here are five friends. They are moving into their new tree house. So, why don’t you help them to decorate their new home with all these things.” The first 10 minutes of the study was videotaped for analysis purposes by using two cameras to ensure that all details were recorded. The activity on the tabletop was also recorded using Camtasia software. The children’s names were replaced with a code. Only the codes were used in data analysis or in the presentation of the data.

At the end of the study, the researcher asked the children about their preferences and experiences. Each child was given a sticker as a token of appreciation. About a week later, the researcher interviewed each child individually in order to measure fantasy play predisposition.

3 Results

All children, except one boy who simply refused to, enjoyed playing with the physical tree house. They engaged with the physical toys and immersed themselves while playing. The virtual tree house, on the other hand, appeared to be much more problematic. Children did not show any surprise for the technological setting initially, as if they were already used to it. Soon, however, they started experiencing a number of difficulties in the interaction, which tended to frustrate them.

Training phase. The training phases lasted an average of 2.30 minutes during which, children only moved 2 balls on average. A strong individual difference was found with one child being capable of moving all the balls (N=7) and 6 children failing to move any of them. At the beginning of the training, children were very concentrated on the task. After a few unsuccessful attempts, some children lost interest in the game, yet they all wanted to play with the virtual tree house. We hoped that the more engaging environment would foster their motivation, and that practice would improve their performance.

Play phase. The following analysis concentrated on movement actions performed during play, e.g. every attempt made from a child to move one object from position x to position y. A total of 882 actions were collected.

They were clustered in 3 categories (no movement, target fail and correct), by interpreting the children intention based on the interaction context and their verbal comments. No-movement included all unsuccessful actions where, despite the child intention, the object did not move from its initial location. Target miss included actions where the objects was moved to a wrong location. This could happen either because the children could not properly control the object trajectory or because they did not lift their finger at the end of the movement. Correct actions included all successful movements. Frequencies and percentages for all four categories are reported in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Moving actions</th>
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<td></td>
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<tr>
<td>Virtual tree</td>
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<td>No movement</td>
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<td>Target miss</td>
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<td>Correct</td>
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Even though children’s performance improved with practice (not shown), the success rate was still very low (35%). The major problem for children was to initiate a movement, whereas precision did not appear to be a major issue. A strong individual difference was observed. The distribution of correct actions ranged from a minimum of 12% to a maximum of 75%. Interestingly, no correlation was found between object size and probability of success.

There were several reasons for unsuccessful actions; some of them were related to our specific application design, whereas others were more generally related to the interaction setting. In this paper, we mainly concentrate on general problems. One of the main problems was that children very often tended to put two hands on the table and constantly had to be reminded not to. The need not to touch the table at two points simultaneously was clearly an obscure constraint to them, and for some
children the only solution was to ask them to put one hand on their back whilst playing.

Most children experienced some failures to make the target stick to their finger while dragging. Children found it difficult to point to the object with only one finger as in Figure 5 (b). Rather they tended to lean their forearm or other fingers on the surface to support their action as in Figure 5 (a). This incorrect posture seems to be afforded by the small size of children with respect to the table height. In the experimental setting children were initially invited to play seated, but asking them to stand up significantly improved interaction.

![Figure 5: Typical hand postures during the interaction](image)

Some very unusual hand gestures were spontaneously adopted by children in their attempts to move objects, as shown in Figure 5 (c and b). Children often used two fingers or their thumb, as if they wanted to better control the movement. In these cases, it appeared that the objects stuck more easily.

Another recurring problem was that children tended to relax on the chair while they were seated and did not put their feet on the mat in the correct position (Figure 6).

![Figure 6: Typical feet position during the interaction](image)

They often touched it only with their toes or with the corner of their feet. Children were perfectly aware that they had to touch the mat, but once again they easily forgot this requirement. Asking them to take their shoes off, and to stand up while playing strongly improved performance.

Other typical interaction problems were due to the fact that some children tended to suck their fingers, had difficulty reaching objects on the opposite side of the table, and sometimes tried to climb on the table to reach far away objects.

### 4 Conclusion

The study reveals that young children may experience several difficulties using a DiamondTouch tabletop device efficiently, but also that they are well motivated to do so. There seem to be two basic rules, which can be applied to maximize the success of the interaction:

(a) Children should play while standing on the mat. (b) Children should be invited to take their shoes off before playing.

To be successful these rules should be incorporated into the game environment so that children will be less likely to move from their position. Inviting children to play while standing is not a panacea, as they tend to lean more on the table and block the projection of the image with their bodies. This is particularly serious in the case of girls with long and curly hair, which did end up on the table hiding most of the screen.

It is also instrumental that the tabletop structure is extremely solid as we witnessed several attempts to climb on the table in order to reach far away objects. Our research has now focused on the design of a new application, using the lessons learned in the study reported in this paper to make the tabletop more engaging and improve the children’s experience with it.

### 5 Acknowledgements

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### 6 References


9.3 Appendix 3: Publication 3

The Fantasy Table

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ABSTRACT
We explore the possibility of creating an interactive system which can foster fantasy play in preschool children in a tabletop environment. This paper reports our experiences designing and testing two prototypes with young children aged 3-4 years old. In the first study, we focused on understanding the similarities and differences between the type of play afforded by real objects and virtual objects. In the second study, we focused on testing solutions for the interaction difficulties evinced in the first study to see how to provide an engaging experience for children. Data were collected by observing children while they played with the study materials. Both quantitative and qualitative methods were used for data collection and analysis.

Categories and Subject Descriptors
H.5.2 User Interfaces: Evaluation/methodology.

General Terms
Design, Experimentation, Human Factors.

Keywords
Fantasy play, preschool children, tabletop interfaces, physical and virtual objects.

1 INTRODUCTION
A call for action to overcome the conflict between creativity and electronic games was launched almost a decade ago by researchers at MIT who acknowledged the risk of leaving the "children as passive consumers of adult conceptions of childhood" resulting "in play that is driven by the toy rather than the other way around" [4]. Despite a growing interest in designing technologies which suit the unique requirements and needs of children, little is known yet on how to support creativity, fantasy and imagination with electronic toys and tools. This knowledge gap tends to increase when pre-school children are considered in spite of a broad corpus of developmental psychology and education research stating a clear relationship between fantasy play and the development of cognitive, emotional and social skills [2].

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Fantasy play is an unstructured and spontaneous activity involving imagination which occurs when children move from real into imaginary worlds and give new meanings to objects they are playing with. For example, a broom can be transformed into a horse, a sheet of paper can be used as a plate, or a long wooden stick can become a sword to fight imaginary monsters. Fantasy play evolves from the second year of life throughout childhood, manifesting more complex symbolic attributions and structures as children grow older [2]. Different types of objects can elicit different types of fantasy play according to the developmental stage of a child [15], but a constant characteristic of young children is their attraction to physical objects which can be touched, held and manipulated. Empirical research suggested that tangible interfaces can stimulate fantasy play when children interact with technologically-enhanced real toys [4]. Less is known about the potential for virtual objects to elicit fantasy play.

Although a large corpus of research has accompanied the design of tangible, desktop and mixed interfaces for virtual games, comparison between these environments are very rare. A recent qualitative study led researchers to believe that physical environments may engage young children (4-6 years old) more than desktop environments [8]. The focus of the study was on learning, and the differences between the two contexts transcended the nature of the objects to be manipulated. Hence, results cannot help to understand the differences between real and virtual stimuli in fantasy play.

This paper reports the results of two studies aimed at investigating the degree to which spontaneous fantasy play can be elicited in 3-4 years old children by virtual environments implemented on a MERL DiamondTouch multi-user interactive tabletop device [6]. This target user is still underexplored in the Interaction Design for Children literature, and at the time of the study there was almost no empirical evidence to suggest that young children could use an interactive tabletop device efficiently [13]. The studies were conducted to investigate whether and how children of such young age interact with virtual tabletop environments, and whether different types of objects (virtual and physical) elicit different patterns of fantasy play engagement. After a review of related work, we present the design environment and two studies in which young children where observed while playing. The paper concludes by reporting design guidelines and suggestions for further work.
2 BACKGROUND
This research concentrated on children aged 3-4 years old. Piaget characterises this period of childhood as part of a preoperational stage (2-7 years old) of cognitive development [17]. Throughout the preschool years, children show a dramatic increase in representational activity, as reflected in the development of particular cognitive, language and motor skills, but they still have several cognitive and social limitations [2, 5]. Children at this age become more aware of what other people are doing and try to imitate them. However, they are easily distracted by perceptual appearance and fail to understand that their own viewpoint can be false. An important limitation of their cognitive abilities is egocentrism, in the sense that they are unable to understand situations from another person’s point of view. Another limitation is centration, which is the tendency to focus attention on a single aspect of a situation and neglect others. Interaction design aimed at children in this age group may be faced with very specific challenges associated to these limitations.

2.1 Fantasy Play
Play is an important part of children’s life which allows them to develop, act out and share their understanding of themselves, others and the world. By playing, children explore and test their knowledge of the real world and increase their ability to communicate with others [16]. Children play in many ways. A common and important type of play is fantasy play, also known as pretend, make believe, imaginative or symbolic play [9]. Fantasy is the product of the mental activity involving imagination that purposely projects new meanings onto objects without the constraints of reality [10]. Children tend to act out their fantasy while playing, using objects and toys as props for their acting. The occurrence of fantasy play and its complexity varies from one child to another, according to their level of maturity and to the objects available for playing [16]. The style and frequency of fantasy play is subtly affected by the appearance of these objects. McLoyd differentiates objects based on their degree of structure [15]. High-level structure objects are replica representations of real objects in the real world whose meaning is known to children (e.g., dolls, toy cars, and toy dining sets). Low-level structure objects have less direct association with the real word and children have more difficulty understanding their meanings (e.g., plastic shapes, pipe cleaners, and wooden blocks).

The development of fantasy play unfolds over several years [2, 14, 19]. In the early stages, children under 2 years of age imitate actions using high-level structure objects. For instance, they can eat from a toy plate using a toy spoon or use a toy bottle to feed a baby doll. At this stage, children have difficulty giving realistic objects, which already have a clear meaning or function, a new meaning. After the age of 2, children gradually learn to use their imagination and use a range of more low-level structure objects. For example, they can use a wooden block as a cake for the doll’s dinner. They also learn to shift from using themselves as agents of their fantasy (i.e. brushing their own hair) to acting on their fantasy on others (i.e. brushing the baby doll’s hair).

From the third year of their life, children start realizing that the agents of their fantasy play can be independent of themselves (i.e., a mother doll brushes the baby doll’s hair). At around this age, fantasy play moves from a solitary activity (children play without connection to their peers) to a parallel activity (children play individually but tend to imitate each others’ activities). High-level structure objects are still the favourite target and stimulus of fantasy play, although children are capable of engaging in more creative exploration of low-level structure objects [15]. High-level structure objects allow children to act on them directly, whereas low-level structure objects afford substitutions or the projection of new meanings into objects (e.g., a square block is transformed into a table). Fantasy play increases steadily during the following years. At the age of 4, children can create and combine ideas, coordinates their play in the context of the real world and problem solving. Fantasy play becomes more social and children start sharing and co-ordinating their fantasies with others. As they grow older, collaborative fantasy play increases while non-collaborative fantasy play decreases [2]. Studies that investigated symbolic attributions of young children have traditionally been based on the observation of children during free play [e.g., 15, 19]. Doll houses are often used as props because they provide a familiar context of daily life routine that can be easily enacted by children during fantasy play.

2.2 Fantasy Play and Technology
Most of the work on fantasy play in the HCI literature has explicitly concentrated on story telling [3, 4, 18]. StoryMat [4], for example, is an interactive mat composed of a set of technology augmented physical toys designed to support collaborative storytelling. The stories created playing with StoryMat were recorded and replayed by the user. Studies that investigated symbolic attributions of young children have traditionally been based on the observation of children during free play [e.g., 15, 19]. Doll houses are often used as props because they provide a familiar context of daily life routine that can be easily enacted by children during fantasy play. Studies that investigated symbolic attributions of young children have traditionally been based on the observation of children during free play [e.g., 15, 19]. Doll houses are often used as props because they provide a familiar context of daily life routine that can be easily enacted by children during fantasy play.

3 FANTASY TABLE
The Fantasy Table is an interactive tabletop environment developed to investigate the degree to which spontaneous fantasy play can be elicited by visual interfaces. The target audience for the table consists of children between the ages of 3 and 4. These ages represent an important stage in fantasy play development, as children become more comfortable experimenting with low-level structure objects and start to engage in imaginative play that involves substitutions and creating similar stories. SAM [19] is an embodied conversational agent engaging children in collaborative storytelling using both physical and virtual objects. StoryTable [3] is a tabletop application requiring users to select information carried on virtual lapboards to create a coherent story. User evaluation of all these devices revealed the value of technology to support explicit story telling, but it offered little information on children’s spontaneous fantasy play with virtual objects.

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tables by the teacher to allow children a wide variety of contexts to experiment with. The MERL DiamondTouch (DT) tabletop [8] was selected as it was available at the university. It has to be noted that at the time of this decision (Spring 2007) there was a complete lack of research evidence on performance of young children using the DT table, which anyway was one of the very few interactive technologies allowing group interaction and multiple simultaneous inputs.

3.1 The MERL DiamondTouch Table
The DT is a large multi-user touch surface (76cm length x 60cm width) which supports group interaction. It is a front-projected table providing input to a computer which in turn drives the projector. The interaction is mediated by touching the table surface with a hand, a finger or with a conductive object. The standard interaction modalities are pointing and drag-and-drop, although more complex gestures can be implemented [6]. The DT can process multiple inputs produced by up to 4 people simultaneously. Each user has a separate receiver, a thin rectangular mat (60cm length x 30cm width) which is normally located on the user’s chair. Sensors embedded in the screen of the tabletop transmit signals from the touch surface via the user’s body to the mat. This information is used by the tabletop to differentiate between different users and coordinate their inputs.

One of our major concerns was that the children would not remain sitting. The receiver mats were therefore located on the floor instead of on the chairs. Two plastic children’s stools were put on top of the mats so that the connection with the mat would not be lost if the children decided to stand-up (Figure 1).

3.2 Formal Evaluations
Two formal evaluations of different prototypes were run in different primary schools in Manchester, UK. Ethical approval was granted for the entire project from the University of Manchester ethical committee and the researchers strictly adhere to the procedures and regulations of the schools. All researchers underwent Criminal Record Checking in order to be allowed to interact unsupervised with the children.

The first evaluation was aimed at collecting user requirements and tests the suitability of the tabletop environment for the target user group since there were no published reports on the matter at the time the study was planned. The study explored whether virtual and physical playing environments tended to elicit different patterns of fantasy engagement. This was an important step towards understanding how much of the current psychological background could be used to inform design. The second evaluation, of a summative nature, was aimed at measuring the degree to which problems and difficulties that emerged in the first evaluation could be solved by a better interaction design.

4 STUDY 1: THE TREE HOUSE
A formative study was performed to collect requirements for design and improve our understanding of fantasy play in real and virtual environments. In particular, we focused on the analysis of similarities and differences between the type of play afforded by real and virtual objects. Data were collected observing children who played with both a physical tree house and a virtual tree house implemented on the DT table.

4.1 Play Environments
A wooden tree house was designed and built by one of the authors for the purpose of this study (Figure 2). The design was an elaboration of the doll house presented in [19] with the objective of creating a gender-neutral play environment. The tree house was built using a range of natural materials. A rectangular wooden board was used as the base. A tall wooden block, covered by real twigs, was used as the trunk. Green sponges were used as grass and leaves. The tree house had 4 open plan platforms attached to the trunk and connected to each other by wooden stairs and a rope. The entire construction was 50cm length, 30cm width and 62cm height. During the study it was located on a coffee table (60cm L x 60cm W x 34cm H).
High-level structure and low-level structure objects were provided for the children to play with and ordered on the table before the evaluation as shown in Figure 2. High-level structure objects were house-related miniatures including five human looking wooden dolls (two males, two females, and one baby) and a number of wooden props suitable for the house environment (a chair, a sofa, a TV, a lamp, a table, a vase and a toy car). The low-level structure objects included two small rocks, two wooden sticks of different sizes, and a set of coloured wooden blocks of different shapes. The set of objects used is illustrated in Figure 3.

A replica of the real tree house was designed and implemented in Macromedia Flash (Figure 4). Great care was devoted to create a 2D design as similar as possible to the real tree-house, in terms of appearance (i.e., proportions, colours and shape). Drawings of the same types of objects included in the wooden tree house were included. These drawings were also as similar as possible to the real objects, in terms of dimensions, colours and shape.

A set of multimodal features were associated with the virtual objects. All of them featured a sound when moved. The sound differed based on shape and type of objects. It could be a word (‘hi’, ‘hello’) for the adult dolls, a giggling (‘gaagaaguuguu’) for the baby doll, a realistic sound (horn for the car and click-click for the lamp), or a simple sound such as ‘boink’, ‘dong’, ‘blip’ for the other objects. Some animations were also present. The dolls waved and the TV played music when moved, the stick could be thrown and would bounce around the screen. Some objects also triggered animations when they overlapped. For example, the dolls changed to party dress and performed a short dance.

4.2 Pilot Testing
Two sets of pilot studies were conducted. The physical tree house was tested with a sample of 8 children (3-8 years old) matched into same age dyads who were invited to play with it, in their own house. A second pilot study was conducted in a usability laboratory of the Manchester Business School with a sample of 4 children (2 ½ - 5 years old) who played with both the virtual and the real tree house. Overall, the pilot studies indicated that the real tree-house was very successful in engaging children of all ages. No major problems were observed when children interacted with the virtual tree house. Even the youngest child was capable of moving the objects on the tabletop successfully. However, children needed to be frequently reminded not to touch the table with two hands. They appeared to be very concentrated while operating the tabletop and demonstratively preferred to play with the real tree house.

4.3 Participants
Parental permission to take part in the study was obtained for 25 pupils of the nursery at the Webster Primary School, in Manchester (UK). According to the report by Ofsted (the official UK body for inspecting schools), this school serves a neighbourhood with a high degree of social disadvantage. The majority of the children come from minority ethnic backgrounds and over half of the pupils are refugees or asylum seekers. Many of them do not speak English when they arrive at the school.
On the day of the study, one girl and one boy refused to participate and one boy was absent. Therefore, the study involved a total of 22 pupils (12 boys and 10 girls). All of them were between 3 and 4 years old (mean = 44 months, sd. = 4.3 months). Prior to the study, they were paired in same gender dyads by the teacher based on existing friendships to encourage collaborative play. One of the girls was a special needs child.

4.4 Design
The study employed a within-subjects design. All the children played with both the physical and the virtual tree house. The order of playing was counterbalanced across dyads and gender.

4.5 Procedure
The study was conducted in a corner of a large schoolroom during school time. The environment was often noisy as the room was used by other teachers and pupils, and the experimental location was separated only by screens. The physical and the virtual tree house were located next to each other, but only one was visible at any time.

Two researchers conducted the study; one interacted with the children, while the other operated the equipment. Prior to the study, the main researcher had spent a few days in the nursery to build a relationship with the children. Each dyad was accompanied by the main researcher to the location of the study. Here, they were introduced to the assistant and explained safety procedures and other information such as the location of the toilet. Paper wristbands of different colours were secured to each child’s wrist for easy recognition.

In the real tree house condition, the researcher simply invited children to play. In the virtual tree house condition, the experimenter helped children with a simple training task involving dragging balls into a rectangular box before play began (Figure 6). Successful movements were acknowledged by a sound.

![Figure 6: Training task (Study 1)](image)

During the training phase, basic rules were explained such as the need to keep the feet on the mat, to avoid touching the table with two hands, and to avoid leaning over the table and block the image from being projected on the table. Play with the virtual tree house started after the training phase when an avatar spider presented the virtual tree house: “Hello, my name is dingle dangle. Here are five friends. They are moving into their new tree house. So, why don’t you help them to decorate their new home with all these things.” In each condition, children were allowed to play for 10 minutes. The evaluation was interrupted earlier if children asked for it, showed any signs of distress, demonstrated to be bored, or got distracted from the tree house for longer than two minutes. At the end of the study children were given a sticker as reward.

Children’s behaviour was recorded for analysis purposes. In the physical setting, there were two cameras covering different angles. In the virtual setting, one camera was used to record the children’s behaviour and Camtasia Recorder software was used to record the movement of objects on the tabletop.

4.6 Data Analysis
Before analysis, all children’s names were replaced with a code and the actual evaluation time was recorded. A fine grained analysis of the 22 videos of children’s play behaviour was conducted noting when a child moved an object from one position to another (moving actions). In order to support this analysis, A4 pictures of the two play environments were divided into rectangular areas according to a grid pattern (Figure 7) and each area was given a unique number. Each object was also associated with a numeric label.

![Figure 7: Area grid coding scheme](image)

The videos were further analysed based on event-sampling, an approach whereby observers record all instances of a particular behaviour during a specified time period. Events of interest were bouts of fantasy play and the time interval was set to 1 minute. Following a conservative approach, bouts of fantasy play were deemed to occur only in presence of explicit verbalisation or unambiguous vocalization of a sound conventionally associated to an object, such as “vroom” for a car, or “splash” for water [15]. This approach is recommended in developmental research as it discriminates between actual fantasy play and other form of behaviour. Actions can be driven, for example, by limited object affordances or by the reproduction of the object conventional use.

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Only language allows ambiguous identification of the children’s denotative intentions. For each bout of fantasy play, the *literatim* transcription of the children’s words and vocalisations was provided alongside important contextual indicators, such as a description of their actions, gestures, and emotions. Following the methodology proposed in [15] bouts of fantasy play were analysed based on the following variables (a) variety of themes: the number of different story themes that emerged during play; (b) object substitution: the number of times an object was transformed into a different entity or some of its characteristics were modified (e.g., colour, size, gender); and (c) object onomatopoeia: the number of different vocalisations of a sound connected with an object. Some 70% of the analysis completed by one researcher was checked by another researcher and all discrepancies were discussed and resolved.

4.7 Results

The evaluation of the real tree house condition lasted an average of 320 seconds (sd = 182 sec.) and that of the virtual tree house an average of 300 seconds (sd = 170 sec.). This difference was not significant, as demonstrated by a Wilcoxon signed rank test. Rather, times in the two conditions were highly correlated (r = .87, p < .001) reflecting differences between dyads in levels of engagement with the study. Strong individual differences were also evident in the wide distribution of evaluation times in both conditions, ranging from 69 to 600 seconds in the real tree house condition, and from 135 to 600 seconds in the virtual tree house condition.

Table 1 shows the moving actions for the physical and virtual environments respectively. Actions were classified as (a) no movement – children tried but could not move the object from its starting point; (b) failed movement – children moved the object but missed the target position and; (c) correct movement – children moved the object successfully to the target position. In the virtual environment, the majority of moving actions were unsuccessful, due to no movements or failed movements. These problems were rare within the physical environment and mainly occurred when objects slipped from the children’s hands as they tried to grasp them from the table (no movements) or fell to the floor as the children tried to place them on the tree house (failed movements). A detailed analysis of the interaction difficulties that emerged when children tried to operate the table-top was presented in [13]. Here we summarise the most common problems.

Most children tended to put both hands on the table which made interacting with the objects impossible. Similarly, children used a variety of gestures to point at objects, many of which used more than one contact point with the table. The requirements that the tabletop needed to be touched with only one body part at any time was clearly an obscure constraint for the children. Some children found it difficult to attach objects to their fingers due to the small size of these objects.

Most children tended to move their feet while playing with the tabletop. This meant that contact with the conductive mat was not always maintained causing interaction to break down.

The number of objects moved from their initial position was not significantly different in both environments (mean = 14, sd. = 6.4 in the virtual tree house; mean = 17, sd. = 8.6 in the real tree house). Yet, the percentage of engaged objects (objects moved to or within the tree house) out of the total number of correct movements was very different. On average, participants in the physical tree house condition engaged 80% of moved objects; whereas participants in the virtual tree house engaged only 39% of moved objects. Very little verbalisation was recorded during the study thus decreasing the possibility of unveiling fantasy play. The following is an example from a dyad that played silently during both evaluation sessions.

**Verbalisation** as responsible for 10 of the cases. In the virtual condition and was subject to high individual variations in both environments. In the physical condition, a total of 24 fantasy bouts were observed. They were produced by 5 of the 11 dyads but one dyad was responsible for 10 of the cases. In the virtual condition, only 5 bouts of fantasy play were observed. They were produced by 2 of the 11 dyads but one dyad was responsible for 4 of the cases.

Table 2 reports the mean number of themes, object substitutions and onomatopoeia per fantasy play bout in the two experimental conditions. A major difference can be noted in the larger occurrence of onomatopoeia when children played in the real environment rather than in the virtual one. Fantasy play bouts which occurred in the real environment were also more complex in terms of story themes enacted by the child, whereas no difference was found in terms of object substitutions. In general, fantasy play themes tended to concentrate around the props available. A strong preference for stories relating to real persons (enacted by the dolls) was found. The few occurrences of object

**Table 1: Moving actions**

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virtual tree house</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No movement</td>
<td>514</td>
<td>58%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>72</td>
<td>8%</td>
</tr>
<tr>
<td>Correct movement</td>
<td>296</td>
<td>34%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>882</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Physical tree house</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No movement</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>22</td>
<td>4%</td>
</tr>
<tr>
<td>Correct movement</td>
<td>475</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>500</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 2: Fantasy play characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Themes</th>
<th>Substitution</th>
<th>Onomatopoeia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virtual house</strong></td>
<td>1.2</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td><strong>Physical house</strong></td>
<td>1.7</td>
<td>0.7</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 2 reports the mean number of themes, object substitutions and onomatopoeia per fantasy play bout in the two experimental conditions. A major difference can be noted in the larger occurrence of onomatopoeia when children played in the real environment rather than in the virtual one. Fantasy play bouts which occurred in the real environment were also more complex in terms of story themes enacted by the child, whereas no difference was found in terms of object substitutions. In general, fantasy play themes tended to concentrate around the props available. A strong preference for stories relating to real persons (enacted by the dolls) was found. The few occurrences of object
substitutions present in the corpus are illustrated in the following example (the stone was transformed into a star, the dolls into fighters, and the sticks into swords).

[Jack (boy, 3 ½ yrs) and Tom (boy, 3 ½ yrs) play together with the real tree house]
Jack: Wiskihihi (Moves the boy doll over Tom’s hand) (fighting movement) He grabs the girl doll from platform 14, picks up the stone from the table and moves it to platform 14! I’ve got star. (Proud tone)
Tom: Picked it up (Point to the stone and plays at platform 14) I’ve got stone! I got the star! (Proud tone)
(Tom and Jack enact fighting actions using the objects available at platform 14 – dolls, sticks, and stone - with vocalisations).

Tom: Bush. Bush. I’m the stone adventurer!
Jack: Blowwew. Blowweew. (Continue playing in a while) I’ve got the stick.
Tom: Dush! Dush! (They play together using sticks as swords. Tom picks the lamp from the table, puts it on platform 14 and shows it to Jake) Look, what I’ve got. Dushhhhh! (Pushes the lamp from platform 14)

4.8 Conclusions
The study provided important information regarding behaviour of young children interacting with a tabletop. Despite many usability issues, the children did not appear to dislike the interaction. This can be evinced, for example, by the length of the evaluation time which equalled the time spent with the real tree house. Further evidence was provided by the similar number of objects moved from their original location in the two environments. However, children appeared to play different games in the two conditions. In the real environment, most of the play concentrated around the tree house, and in particular around the stairs and the rope. Dolls and objects were repeatedly bounced up and down the stairs (mimicking climbing) or tied to the rope and swung. Objects were frequently rearranged within and between platforms and used in coordination to each other (e.g. dolls were seated on chairs). In the tabletop environment, they played to move objects independently of the tree house as if the reward laid in achieving the movement. The children tended to spread objects randomly on the screen with little interaction between them and with the tree house. An example of this behaviour is reported in the following extracts from the transcripts.

[Sara (girl, 4 yrs) and Kathy (girl, 3 ½ yrs) play together with the virtual tree house]
Sara: (Drags the baby boy doll very slowly bit by bit) (She is very concentrated) He is going … Look! (Smiles with satisfaction and continues dragging the baby boy very slowly)
Kathy: (Tries to stop Sara) (She wants to drag the baby boy herself)
Sara: Will not let the baby boy go. Slowly she manages to drag the baby boy to the top of the tree house! He’s gone up! (Proud tone, smiles with satisfaction)

The fact that the children did not engage with the virtual tree house could also be due to difficulties in making sense of 3D perspective in drawings, typical of young children [1]. It was striking that no children, independently of presentation order, demonstrated to recognise the similarity between the two environments.

The open plan platforms of the virtual tree house were quite small in proportion to the objects, which may also have hampered the children’s desire to put them on there.

The study did not provide conclusive evidence to the question addressing differences in fantasy play elicitation between virtual and physical stimuli. Indeed, too few examples of fantasy play were recorded in the virtual environment to allow for meaningful comparison. This low number could be reasonably explained by the severe interaction issues evinced with the tabletop. The children were very concentrated on the task at hand (i.e., moving objects) leaving only limited resources for fantasy play. Nevertheless, a few bouts of fantasy play were recorded. They tended to focus on simpler stories than those created in the real environment. Furthermore, real objects tended to invoke frequent vocalisation, whereas this phenomenon was not substantial enough when children interacted with virtual objects. Object substitution was rare in both conditions, possibly reflecting the developmental stage of the children [15]. An example of fantasy play on the tabletop is reported below. This is an interesting example where the fantasy play is achieved by a conjoint effort: Sam is the author, Charlie the partial executor, and in case of difficulty the experimenter is called in to help.

[Sam (boy, 3 ½ yrs) and Charlie (boy, 3 ½ yrs) play together with the virtual tree house]
Sam: Can you do… can you do that car? (Addresses Charlie while trying to drag the car)
Charlie: (Drag the TV) Aahhhhh! (Smile and have fun dancing to the TV music) Listen! Sam: Can you do… can you do that. can you do that? (Point to the car and tries to drag the car)
Charlie: (Tries to help Sam to drag the car)
Sam: This one. (Point at the blue square box) Put it there, put it in the car, put it in the car… put it in the car!
Charlie: (Drag the red triangle to the car)
Sam: Can you… Can you put my doll over there?
(Addresses the experimenter while pointing at the boy)
Charlie: Put the doll there. (Point at the car) Sam: He says hello!

Very little verbalisation was recorded during the entire study. This may have further reduced the possibility of uncovering fantasy play episodes, based on our conservative scoring criteria. Moderate verbalisation is a common behaviour of pre-school children [2,15,19], yet the noisy environment of our evaluation study may have further inhibited verbalisation and vocalisation. The lower level of verbalisation in the virtual tree house can be explained by interaction difficulty and by the intrinsic effect of videogames which tend to shift representational styles from verbal to iconic [12].

5 STUDY 2: THE MAGIC HOUSE
The Magic House was designed to solve some of the problems evinced in study one by a better interaction design. The objective
was to design a simple playing environment which fostered fantasy play. The Magic House was composed of a large room with a big window on the right side and a door with a cat flap at the bottom on the left side (Figure 8). This significantly reduced the geometrical complexity of the playing environment.

To encourage fantasy play, five low-level structure objects were displayed at the bottom of the screen, alongside a magic wand. The drastic reduction in the number of available objects was informed by our previous finding that children did not play with all the objects in the tree house environment, concentrating instead on some favourite targets such as dolls, the TV, and the flower vase. Each object was transformed into a high-level structure object when it was first moved into the room area. The yellow cylinder changed into a boy doll, that waved and said "hi", the blue box changed into a green TV set showing a clip from 'lazy town' (a popular children’s show in the UK), the red triangle changed into a coffee table, the purple square changed into a vase and the green rectangle changed into a girl doll, that waved and said "hello" (Figure 9).

Once in the room, objects could be transformed again by touching them with the magic wand. For instance, the boy changed into a girl, the girl into a baby, the green TV set into a blue TV set showing 'in the night garden' (another popular children’s shows in the UK) and the vase into a lamp. Pictures in the room could also be transformed with the magic wand: the sun changed into the moon, the cat flap triggered an animation of a cat chasing a mouse running across the room, and a spider dropped from the spider web.

To solve the usability problems evinced in Study 1, the size of the objects was increased by 300% as compared to the Tree House application. Furthermore, the plastic chairs were removed and the children were invited to take their shoes off to ensure that their feet connected with the mats correctly at all times. The design was iteratively tested with a 3 year-old child and there were no sign of the earlier usability problems.

5.1 Participants
A total of 12 pupils (6 boys ad 6 girls) aged between 3 and 4 years old (mean = 47 months, sd. = 1.7 months) were recruited from the Martenscroft Nursery School, in Manchester (UK). The Ofsted report states that this school is situated in a neighbourhood with high levels of social and economic disadvantage. The children come from wide range of ethnic backgrounds and almost half speak English as an additional language. On the day of the study, two boys were absent. Thus, the final sample consisted of 10 children (2 couples of boys and 3 couples of girls). All dyads were paired by the teacher based on existing friendships.

5.2 Procedure
The study was conducted in a quiet private room at the nursery. The same procedure described in study one was followed unless stated otherwise. All children participated in two sessions. The first session took place in the morning. The researcher demonstrated how to use the tabletop with a training similar to that of study one but with bigger balls. More emphasis was devoted to the need to touch the table with one hand at the time and children were invited to put their non-dominant hands behind their backs. After the training phase, the spider introduced the Magic House saying “Hello, my name is dingle dangle. Welcome to my Magic House. Find the cat chasing the mouse. Come on and play and have a lot of fun. You can change the moon into a sun. Drag the objects into my room. Wave the wand and say Bing! Bang! Boom!” Children were left to play with minimal supervision and were interrupted only when necessary. The second session took place in the afternoon, when the children were simply invited to play with The Magic House again.

The videos were analysed as in study one, with the exception of the variable engaged objects which was not meaningful in the current study as the entire screen was part of the play environment. Fantasy play was deemed to occur only if it was initiated by the children and not as a reaction to the object transformations performed by the system. As in the first evaluation, fantasy play was recognised only in the presence of explicit verbalisation or unambiguous vocalisation.

5.3 Results
On average the evaluation time was 458 seconds (sd. = 103.3 sec) in the first session and 495 seconds in the second session (sd. = 133.7 sec). One dyad refused to take part in the second session. According to a Wilcoxon test, the slight increase in
section 2 was not significant, possibly due to the small sample size. Evaluation times were strongly correlated between sessions ($r = .94$, $p = .06$), reflecting individual differences.

The fine-grained analysis of the moving actions clearly showed that the children were more successful moving objects in the Magic House prototype as compared to the Tree House prototype (compare Table 1 and Table 3). The increase in successful actions was mainly due to a significant drop in the percentage of no movements, whereas the percentage of failed movements remained relatively stable across studies. A slight improvement occurred in the second session.

<table>
<thead>
<tr>
<th>Session 1</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No movement</td>
<td>10</td>
<td>2%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>29</td>
<td>7%</td>
</tr>
<tr>
<td>Correct movement</td>
<td>403</td>
<td>91%</td>
</tr>
<tr>
<td>Total</td>
<td>442</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 2</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No movement</td>
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<td>1%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>19</td>
<td>4%</td>
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<tr>
<td>Correct movement</td>
<td>443</td>
<td>95%</td>
</tr>
<tr>
<td>Total</td>
<td>469</td>
<td>100%</td>
</tr>
</tbody>
</table>

A total of 21 bouts of fantasy play were found in session 1 and were enacted by 3 out of 5 dyads. A total of 26 bouts of fantasy play occurred in session 2 and were enacted by all 4 dyads. Table 4 summarises the mean number of fantasy themes, object substitutions and instances of onomatopoeia evinced in each fantasy bout in the two evaluation sessions. It shows a very consistent pattern.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Substitution</th>
<th>Onomatopoeia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>1.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Session 2</td>
<td>1.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### 6 DISCUSSION

Our studies suggest that virtual objects can stimulate fantasy play, whenever proper interaction design allows children to engage with them. The first study highlighted a number of interaction problems which are likely to have disrupted the children’s natural disposition towards fantasy play. Some of these interaction problems were solved in the second prototype, demonstrating that the tabletop can be operated by children as young as 3 years old. Successful interaction required large targets, a simple graphical environment, and a number of strategic actions to ensure that the contact between the child and the mat was properly maintained (children stood on the mat without wearing shoes).

Despite the usability problems children experienced in study 1, there was still evidence of some bouts of fantasy play. However, fantasy play occurred much more frequently in study 2 (mean number of bouts per child mb = 2.1 session 1; mb= 3.2 session 2) than in the virtual (mb = 0.4) and in the real conditions (mb = 2) of study 1. Furthermore, the actual number of children who engaged in fantasy play also increased significantly, reaching 100% in session 2 of study two. The higher levels of verbalisation observed in study 2 could be explained by differences in the study environments between the two studies (the one in study 2 being much quieter than the one in study 1), although it may equally well have been caused by the difference in design of the applications, and individual differences between children. Previous research has posited a correlation between fantasy play and social-background of the children [15]. It has to be noted however that the schools used in these studies were located in areas with similar levels of socio-economic disadvantage. Therefore, it seems unlikely that differences in the socio-economic background of the children who took part in the two studies could explain the improved results of Study 2.

The analysis of children’s behaviour in terms of identifying fantasy play bouts is a challenging task. The reliability of our data was improved by the application of a conservative analysis approach, whereby only explicit events were recorded. Little differences were found in the complexity of fantasy play across the two interface design tested. However, the fantasy play bouts elicited by virtual stimuli appeared to involve lower number of story themes and less vocalisation than those elicited by physical stimuli. Further studies are needed and a new prototype will be developed in order to understand what exactly makes children engage spontaneously in complex fantasy play creation with virtual stimuli. This paper offers a methodology and some practical suggestions for this research by showing that virtual objects can stimulate spontaneous fantasy play in preschool children.

### 5.4 Conclusions

Overall, the second prototype solved many of the interaction problems evinced in the first study. The first session of the evaluation lasted almost 3 minutes longer than the average evaluation time in study 1. More importantly the majority of this time was spent actually playing with the system rather than trying to operate it.

Several evidences of fantasy play were noted suggesting that virtual objects have the potential to foster pretend play in very young children. An example is reported below.

[Lily (irl, 3 ½ yrs) and Jane (girl, 3 ½ yrs) play together]

Lily: Two babies. (Two virtual baby dolls are displayed on the screen)
Jane: No. Not two babies.
Lily: OK. This is baby. (Pointing at baby A). This is sister because this one is old enough (Pointing at baby B)
Jane: No. I need a sister!
Lily: OK. I'll change it. (Lily change the virtual baby into a virtual baby by using the magic wand)
7 ACKNOWLEDGMENTS
We thank the Headteachers of the Webster Primary School, and Martenscroft Nursery School for their support to the study and all the children who participated in them.

8 REFERENCES
### 9.4 Appendix 4: Ethnicity Background (Study 1)

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>British</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Irish</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other White</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mixed</strong></td>
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<td></td>
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</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>White and Black African</td>
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<td>2</td>
</tr>
<tr>
<td>White and Asian</td>
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<td>0</td>
</tr>
<tr>
<td>Other Mixed</td>
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<td>1</td>
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</tr>
<tr>
<td><strong>Asian or Asian British</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Indian</td>
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<td></td>
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<td>1</td>
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<td>African</td>
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<td>Other Black</td>
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<tr>
<td>Any other Ethnic</td>
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<tr>
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<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td>12</td>
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</table>

* Other Mixed: Caribbean African White (1), Caribbean African (1)
* Other Black: Somali (3), Black British (1)
* Other Ethnic Group: Middle Eastern (3), Malay (1)
### Appendix 5: Parent’s Occupation (Study 1)

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<th>No</th>
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</tr>
<tr>
<td>2</td>
<td>Advertising, Marketing &amp; PR</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Animal &amp; Planet Resources</td>
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<td>Arts, Design &amp; Crafts</td>
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<td>5</td>
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</tr>
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<td>7</td>
<td>Education Teaching &amp; Lecturing</td>
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<tr>
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<td>9</td>
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<td>Student</td>
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</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
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</table>

* Other: Housewife (6), Shop Cashier (1), Security (1)
## 9.6 Appendix 6: Basic quantitative data on behaviours (Study 1)

### 1) Social behaviours

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>Dyads</th>
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<tbody>
<tr>
<td></td>
<td>MA1</td>
</tr>
<tr>
<td>Agreement</td>
<td>7</td>
</tr>
<tr>
<td>Ask partner to move object</td>
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</tr>
<tr>
<td>Ask object from partner</td>
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</tr>
<tr>
<td>Copy partner</td>
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</tr>
<tr>
<td>Offer object to partner</td>
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</tr>
<tr>
<td>Show object to partner</td>
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</tr>
<tr>
<td>Watch partner</td>
<td>3</td>
</tr>
<tr>
<td>Ask partner not to disturb</td>
<td>2</td>
</tr>
<tr>
<td>Ask partner to stop</td>
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</tr>
<tr>
<td>End the play</td>
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</tr>
<tr>
<td>Prevent partner get object</td>
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</tr>
<tr>
<td>Refuse to play</td>
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<tr>
<td>Steal object from partner</td>
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*P = physical, V = virtual

### 2) Affective behaviours

<table>
<thead>
<tr>
<th>Behaviours</th>
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<tr>
<td></td>
<td>MA1</td>
</tr>
<tr>
<td>Excited</td>
<td>1</td>
</tr>
<tr>
<td>Jump</td>
<td>1</td>
</tr>
<tr>
<td>Laugh</td>
<td>2</td>
</tr>
<tr>
<td>Smile</td>
<td>8</td>
</tr>
<tr>
<td>Surprised</td>
<td>1</td>
</tr>
<tr>
<td>Angry</td>
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</tr>
<tr>
<td>Bored</td>
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</tr>
<tr>
<td>Frustrated</td>
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</tr>
<tr>
<td>Sad</td>
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</tr>
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</table>

*P = physical, V = virtual
Appendix 6: Basic quantitative data on behaviours (Study 1)

### 3) Other behaviours

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>MA1</th>
<th>MB2</th>
<th>MA3</th>
<th>MB4</th>
<th>MB5</th>
<th>MB6</th>
<th>FA1</th>
<th>FB2</th>
<th>FA3</th>
<th>FB4</th>
<th>FA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suck finger(s)</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
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<td>Voice expression</td>
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<td>3</td>
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</tbody>
</table>

* P = physical, V = virtual

### 4) Attention distribution

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>MA1</th>
<th>MB2</th>
<th>MA3</th>
<th>MB4</th>
<th>MB5</th>
<th>MB6</th>
<th>FA1</th>
<th>FB2</th>
<th>FA3</th>
<th>FB4</th>
<th>FA5</th>
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<td>Concentration</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Look around</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Look at mat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Look at demonstrator</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Look at demonstrator's PC</td>
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<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
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<td>Noise distraction</td>
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<td>0</td>
<td>6</td>
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<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Play with hands &amp; shadow</td>
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<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Play with wristband</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Walk away</td>
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<td>1</td>
<td>0</td>
<td>4</td>
<td>0</td>
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<td>0</td>
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</tbody>
</table>

* P = physical, V = virtual

### 5) Demonstrator involvement

<table>
<thead>
<tr>
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<th>MA1</th>
<th>MB2</th>
<th>MA3</th>
<th>MB4</th>
<th>MB5</th>
<th>MB6</th>
<th>FA1</th>
<th>FB2</th>
<th>FA3</th>
<th>FB4</th>
<th>FA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust participant's feet</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>0</td>
</tr>
<tr>
<td>Adjust participant's hand</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Adjust participant's mat</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Adjust tabletop</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>Encourage participant</td>
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<td>0</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Remind participant</td>
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<td>6</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>8</td>
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<td>0</td>
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<td>Remove participant's hand(s)</td>
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<td>0</td>
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<td>0</td>
<td>5</td>
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* P = physical, V = virtual
Appendix 6: Basic quantitative data on behaviours (Study 1)

6) Interaction with tabletop

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>MA1</th>
<th>MB2</th>
<th>MA3</th>
<th>MB4</th>
<th>MB5</th>
<th>MB6</th>
<th>FA1</th>
<th>FB2</th>
<th>FA3</th>
<th>FB4</th>
<th>FA5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
<td>V</td>
<td>P</td>
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<tr>
<td>Children drag the same object</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>7</td>
<td>0</td>
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<tr>
<td>Drag two objects on the same time</td>
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</tr>
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<td>Tap the tabletop</td>
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<td>1</td>
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<td>2</td>
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<td>2</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Two hands on the table</td>
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<td>7</td>
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<td>2</td>
<td>0</td>
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*P = physical, V = virtual
9.7 Appendix 7: Ethnicity Background (Study 2)

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</tr>
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<td>British</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Irish</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other White</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mixed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White and Black Caribbean</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>White and Black African</td>
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<td>1</td>
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<tr>
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<tr>
<td><strong>Asian or Asian British</strong></td>
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<td>Indian</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>Bangladeshi</td>
<td>0</td>
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<td>Other Asian</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Black or Black British</strong></td>
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<td></td>
<td></td>
</tr>
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<td>Caribbean</td>
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<td>0</td>
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<td>African</td>
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<tr>
<td>Other Black</td>
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<td><strong>Chinese or other Ethnic Group</strong></td>
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<td>Chinese</td>
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<tr>
<td>Any other Ethnic</td>
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<tr>
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<td><strong>Total</strong></td>
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* Other Mixed: Indian & British (1)
* Other Asian: Persian (1)
* Other Ethnic Group: Korean (2)
### 9.8 Appendix 8: Parent's Occupation (Study 2)

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<tr>
<th>No</th>
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</tr>
<tr>
<td>2</td>
<td>Advertising, Marketing &amp; PR</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Animal &amp; Planet Resources</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Arts, Design &amp; Crafts</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Construction &amp; Property Management</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Counselling, Social &amp; Guidance Services</td>
<td>0</td>
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<tr>
<td>7</td>
<td>Education Teaching &amp; Lecturing</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Engineering</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Finance &amp; management consultancy</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Heath Care</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Hospitality &amp; Event Management</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Human Resources &amp; Employment</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>IT, Economics, Statistics &amp; management Services</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Information Services</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Insurance &amp; Pensions &amp; Actuarial work</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>Law Enforcement &amp; Public Protection</td>
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<td>18</td>
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<td>19</td>
<td>Logistic &amp; Distributions</td>
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<td>Manufacturing &amp; Distribution</td>
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<td>Sales, Retail &amp; Buying</td>
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<td>26</td>
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<tr>
<td>27</td>
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</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>12</td>
</tr>
</tbody>
</table>

* Other: Housewife (1), Refugee & Asylum Advice Worker (1), Unemployed (1)
  Homeopath (1)
### 9.9 Appendix 9: Basic quantitative data on behaviours (Study 2)

#### 1) Social behaviours

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreement</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Ask for their turn</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ask partner’s opinion</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Ask partner to move object</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Help partner</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Suggest an action</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Watch partner</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ask partner to stop</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Disagreement</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Refuse to play</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
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<tr>
<td>Steal object from partner</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

* 1 = Session 1, 2 = Session 2

#### 2) Affective behaviours

<table>
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<tr>
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<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dance</td>
<td>2</td>
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<td>5</td>
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<td>0</td>
</tr>
<tr>
<td>Excited</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Jump</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laugh</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Smile</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Surprised</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Anger</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bored</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cry</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Frustrated</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Sad</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

* 1 = Session 1, 2 = Session 2
### 3) Other behaviour

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice expression</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>5</td>
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<tr>
<td>Other behaviour</td>
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<td></td>
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</tr>
</tbody>
</table>

* 1 = Session 1, 2 = Session 2

### 4) Attention distribution

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Look around</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Look at mat</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Look at demonstrator</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Look at projector</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Look at demonstrator’s PC</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Play with hands and shadow</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Play with wristband</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walk away</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* 1 = Session 1, 2 = Session 2

### 5) Interaction with the tabletop

<table>
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<tr>
<th>Behaviours</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch animated object</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Catch the avatar</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Children drag the same object</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Drag two objects on the same time</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Drag the object around the screen</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hide object from screen</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sit on the table</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Try to change object in non-active area</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tap the tabletop</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Two hands on the tabletop</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Trigger animation in hot spot areas</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

* 1 = Session 1, 2 = Session 2
6) **Demonstrator Involvement**

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>M1</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encourage participant</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Remind participant</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Remove participant's hand</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</table>

* 1 = Session 1, 2 = Session 2
### 9.10 Appendix 10: Ethnicity Background (Study 3)

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<th>Girls</th>
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<td></td>
</tr>
<tr>
<td>British</td>
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<td>3</td>
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</tr>
<tr>
<td>Irish</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other White</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Mixed</strong></td>
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<td></td>
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</tr>
<tr>
<td>White and Black Caribbean</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>White and Black African</td>
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<td>0</td>
</tr>
<tr>
<td>White and Asian</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other Mixed</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Asian or Asian British</strong></td>
<td></td>
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</tr>
<tr>
<td>Indian</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pakistani</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bangladeshi</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other Asian</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Black or Black British</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caribbean</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>African</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Other Black</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Chinese or other Ethnic Group</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Any other Ethnic</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No Answer</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10</td>
<td>10</td>
<td>20</td>
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</tbody>
</table>

* Other White: Caucasian (1)
* Other Mixed: White & Arabic (1)
* Other Asian: Nepalese (1)
* Other Black: African Caribbean (2)
* Other Ethnic Group: Malay (1)
### 9.11 Appendix 11: Parent’s Occupation (Study 3)

<table>
<thead>
<tr>
<th>No</th>
<th>Occupation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Administration</td>
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</tr>
<tr>
<td>2</td>
<td>Advertising, Marketing &amp; PR</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Animal &amp; Planet Resources</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Arts, Design &amp; Crafts</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Construction &amp; Property Management</td>
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</tr>
<tr>
<td>6</td>
<td>Counselling, Social &amp; Guidance Services</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Education Teaching &amp; Lecturing</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Engineering</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Finance &amp; management consultancy</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Heath Care</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Hospitality &amp; Event Management</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Human Resources &amp; Employment</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>IT, Economics, Statistics &amp; management Services</td>
<td>0</td>
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<tr>
<td>14</td>
<td>Information Services</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Insurance &amp; Pensions &amp; Actuarial work</td>
<td>0</td>
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<tr>
<td>16</td>
<td>Law Enforcement &amp; Public Protection</td>
<td>0</td>
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**Total**

* Other: Barber (1), Beautician (1), Community Activist (1), Housewife (5), Civil servant (1), Unemployed (1)
### 9.12 Appendix 12: Basic quantitative data on behaviours (Study 3)

#### 1) Social behaviours

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* P = physical, V1 = virtual session 1, V2 = virtual session 2

2) Affective behaviours

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Appendix 12: Basic quantitative data on behaviours (Study 3)

| Frustrated | P | 0 | 0 | 0 | 0 | 10 | 0 | 1 | 0 | 0 | 0 |
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| V2 | 1 | 0 | 3 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| Sad | P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| V1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| V2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*P = physical, V1 = virtual session 1, V2 = virtual session 2

3) Attention distribution

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*P = physical, V1 = virtual session 1, V2 = virtual session 2

4) Interaction with the tabletop

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## Appendix 12: Basic quantitative data on behaviours (Study 3)

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</tbody>
</table>

* P = physical, V1 = virtual session 1, V2 = virtual session 2

5) **Demonstrator involvement**

<table>
<thead>
<tr>
<th>Dyads</th>
<th>FA2</th>
<th>FA4</th>
<th>FB1</th>
<th>FB3</th>
<th>FB5</th>
<th>MA1</th>
<th>MA3</th>
<th>MA5</th>
<th>MB2</th>
<th>MB4</th>
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<tr>
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<td>P</td>
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</table>

* P = physical, V1 = virtual session 1, V2 = virtual session 2
Appendix 12: Basic quantitative data on behaviours (Study 3)

6) Other behaviours

<table>
<thead>
<tr>
<th></th>
<th>FA2</th>
<th>FA4</th>
<th>FB1</th>
<th>FB3</th>
<th>FB5</th>
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<th>MA3</th>
<th>MA5</th>
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<th>MB4</th>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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</tr>
<tr>
<td>Voice expression</td>
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<td></td>
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<td></td>
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<tr>
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</tr>
</tbody>
</table>

* P = physical, V1 = virtual session 1, V2 = virtual session 2
### 9.13 Appendix 13: Dyad's play time (Study 1-3)

#### STUDY 1

<table>
<thead>
<tr>
<th>Dyads</th>
<th>Tree House</th>
<th>Convert time to numeric</th>
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<td>MALE 1</td>
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<tr>
<td>MALE 2</td>
<td>00:09:38</td>
<td>9.63</td>
<td>00:06:24</td>
<td>6.40</td>
</tr>
<tr>
<td>MALE 3</td>
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<td>2.40</td>
</tr>
<tr>
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<td>3.88</td>
<td>00:02:32</td>
<td>2.32</td>
</tr>
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<td>10.0</td>
<td>00:10:00</td>
<td>10.0</td>
</tr>
<tr>
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<tr>
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<td>6.98</td>
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<tr>
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</tr>
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<td>00:10:00</td>
<td>10.0</td>
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<td>00:05:07</td>
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#### STUDY 3

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<td>00:09:55</td>
<td>9.92</td>
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<tr>
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<td>2.17</td>
<td>00:04:51</td>
<td>4.85</td>
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<td>9.23</td>
<td>00:07:37</td>
<td>7.62</td>
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<td>00:08:41</td>
<td>8.68</td>
<td>00:06:30</td>
<td>6.50</td>
</tr>
<tr>
<td>MALE 2</td>
<td>00:10:00</td>
<td>10.0</td>
<td>00:06:35</td>
<td>6.58</td>
</tr>
<tr>
<td>MALE 3</td>
<td>00:06:56</td>
<td>6.93</td>
<td>00:04:38</td>
<td>4.63</td>
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<tr>
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<td>8.90</td>
<td>00:08:24</td>
<td>8.40</td>
</tr>
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<td>00:08:50</td>
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<td>00:07:12</td>
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#### STUDY 3

<table>
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<td>10.0</td>
</tr>
<tr>
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<td>8.63</td>
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<td>7.85</td>
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<tr>
<td>MALE 4</td>
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<td>8.70</td>
</tr>
<tr>
<td>MALE 5</td>
<td>9:62</td>
<td>9.62</td>
</tr>
</tbody>
</table>
MANCHESTER BUSINESS SCHOOL

Consent form

Title of Project:
Fantasy Play in Real and Virtual Environments

The parent/guardian should complete the following section.

1. Have you read the Parent Information Sheet? YES/NO
   
2. Have you received enough information about the study? YES/NO
   
3. Do you consent to be audio taped/video taped/photographed as detailed in the Parent Information Sheet? YES/NO
   
4. Do you understand that your child do not need to take part in the study and if your child do enter your child are free to withdraw:
   * at any time
   * without having to give a reason for withdrawing
   * and without detriment to you
   YES/NO

5. Do you/your child agree to take part in this study? YES/NO

Name of child: ....................... Signed: ....................... Date: ...................
(parent/guardian)

Name of researcher: ..................... Signed: ....................... Date: ...................

This project has been approved by the
Manchester Business School Research Ethics Committee
Parent Information Sheet

Title of project:
Fantasy Play in Real and Virtual Environments

Introduction
Dear Parent(s) / Guardian(s),

My name is Evi Mansor and I am a PhD student working under the supervision of Dr Antonella De Angeli at Manchester Business School, University of Manchester where I am currently conducting a study on fantasy/pretend play in preschool children ages 3-4 years old.

Your child is invited to take part in this study. Please read the following information carefully and discuss it with your child. Feel free to contact me if there is anything that is not clear or if you would like more information.

What will my child have to do if he/she takes part?
The study will be conducted at the Webster Primary School from 3rd March 2008 – 19th March 2008. The class teacher will assign your child based on their friendships and each research session will involve two children. A guide of the exact procedure will be provided and explained to your child before the session. The session will be audio/video recorded with your consent to allow us to transcribe the children’s responses. All research team members have completed the Criminal Records Bureau checks.

A) Part 1 - Observation
Children will be asked to “play” in pair alternately in two different conditions for 10 minutes in each condition and I will observe their behaviour. I’ll take extreme care to use a language which is appropriated to your child age. Class teacher is invited to observe the study.

Condition 1 (Physical setting)
Children will be asked to play with physical objects in pairs on the provided small table with physical materials given (a wooden tree house, realistic and non realistic objects) to support their play.

Condition 2 (Virtual setting)
Children will be asked to play with virtual objects in pairs on the tabletop environment (60cm x 76cm) using the software that will be developed by the researcher. The software will contain a virtual tree house and virtual realistic and non realistic objects. Extra features will be included such as animations and sounds. Children can select, drag or organise the virtual objects on the table surface by using their fingers.
The *DiamondTouch* table will be used as interactive device. *DiamondTouch* is a front-projected table linked to a computer and a projector. Users can retrieve and interact with computer based resources by touching the surface of the table with their fingers. A short demonstration on how to use the application will be conducted by the researcher. Then, participants will be invited to “play” with the software with their partner and the researcher will observe their behaviour. A person (research assistant) will sit next to the table in case the children will need help while they are using the application.

At the end of the observation sessions, the researcher will briefly ask the children about their experience and preferences. Completion of the task will require approximately 30 minutes.

**B) Part 2 - Interview**

A week later, the children will be interviewed one by one by myself and complete two short language tasks after an initial chat. During the first part of the interview they will be asked to name their favourite story, favourite toy, favourite TV show, favourite game and they will also be asked about their imaginary companion/friends. After this initial chat they will be asked to complete two tests: a vocabulary test and a perspective taking test. During the vocabulary test the children will be given a word and a selection of four pictures. Their task is to select the picture that corresponds to the word they have just heard. During the second test they will take part in a short guessing game in which they have to find the location of a hidden object. The interview will last approximately 20 minutes.

**Will the data be anonymous?**

Yes, the children’s names will never be used during the publication of the results. For analysis purposes, each child’s name will be replaced with a code. Only the codes will be used in presentations of the data.

**Will the data be confidential?**

Yes, only the research team will have access to the data. The data will be kept strictly confidential. Forms, written records, audio and video recordings will be kept in a secured unit in the Manchester Business School and electronic data will be kept in a password protected computer. The data and consent forms will be kept for a period of 5 years for the purpose of publishing the results.

**Does my child have to take part?**

Participation is entirely voluntary. If you and your child decide to take part please fill in the attached consent form. Please note that even if your child decides to take part, he or she is free to withdraw from the study at any time with no need to justify his/her decision. Similarly, you may decide to withdraw you child’s participation in the study at any time if you wish so. I will take particularly care to interrupt the study if the child show any sign of distress.

**Where can I obtain further information if I need it?**

If you have any further questions or queries please contact:

Evi Mansor (PhD student): Evi.Mansor@postgrad.manchester.ac.uk

Dr Antonella De Angeli (Supervisor): Antonella.De-angeli@manchester.ac.uk
MANCHESTER BUSINESS SCHOOL

Questionnaire for Parent/ Guardian to Answer

Your name: ______________________________________

Your occupation: (Put a tick in ONE box only)

☐ Administration
☐ IT, Economics, Statistics & management Services
☐ Advertising, Marketing & PR
☐ Information Services
☐ Animal & Planet Resources
☐ Insurance & Pensions & Actuarial work
☐ Arts, Design & Crafts
☐ Law Enforcement & Public Protection
☐ Construction & Property Management
☐ Legal Services
☐ Counselling, Social & Guidance Services
☐ Logistic & Distributions
☐ Education Teaching & Lecturing
☐ Manufacturing & Distribution
☐ Engineering
☐ Natural Resources & the Environment
☐ Manufacturing & Property Management
☐ Publishing, Media & Performing Arts
☐ Counselling, Social & Guidance Services
☐ Sales, Retail & Buying
☐ Hospitality & Event Management
☐ Scientific Services
☐ Human Resources & Employment
☐ Student

Other : ________________________________

Your child's name: ________________________________________________________

Your child's date of birth: ________________________

Your child's gender: ☐ male ☐ female (Please tick one)

Does your child have any other sibling? YES / NO (Please circle your answer)

If so, then how many? ___________

What number is your child? _______

Your child's ethnic group? (Put a tick in ONE box only)

A. White British

British ☐
Irish ☐
Any other white background (please write in)

B. Mixed

White and Black Caribbean ☐
White and Black African ☐
White and Asian ☐
Any other mixed background (please write in)

C. Asian or Asian background

Indian ☐
Pakistan ☐
Bangladeshi ☐
Any other Asian background (please write in)

D. Black or Black British

Caribbean ☐
African ☐
Any other Black background (please write in)

E. Chinese or other ethnic group

Chinese ☐
Any other ethnic group background (please write in)
Your child’s likes and dislikes

What is your child’s favourite story?

____________________________________________________________________________

What is your child’s favourite toy?

____________________________________________________________________________

Your child’s favourite TV show?

____________________________________________________________________________

Your child’s favourite game?

____________________________________________________________________________

Does your child have a pretend/imaginary friend? YES / NO (Please circle your answer)

If yes, can you describe his/her imaginary/pretend friend?

____________________________________________________________________________

____________________________________________________________________________

Your child and computers

At home, how often does your child use the computer per week?

Never ☐ Less than 30 minutes ☐ I don’t know ☐

30 minutes -2 hours ☐ More than 2 hours ☐

At the nursery, how often does your child use the computer per week?

Never ☐ Less than 30 minutes ☐ I don’t know ☐

30 minutes -2 hours ☐ More than 2 hours ☐

What does your child use the computer for?

(Please tick all that apply)

☐ Play games
☐ Watch programs (e.g. kids programs, cartoons)
☐ Educational purposes
☐ Other (please write in) __________________________________________

Thank you for completing this questionnaire. Please complete and return this questionnaire to the Nursery Teacher.

This project has been approved by the

Manchester Business School Research Ethics Committee
### Frequency of computer usage among participants at home - per week

<table>
<thead>
<tr>
<th>Computer Usage</th>
<th>Study 1</th>
<th>Study 2</th>
<th>Study 3</th>
</tr>
</thead>
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<tr>
<td>I don’t know</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>More than 2 hours</td>
<td>2</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>30 minutes – 2 hours</td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Less than 30 minutes</td>
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<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Never</td>
<td>7</td>
<td>3</td>
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</tr>
<tr>
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<tr>
<td><strong>Total</strong></td>
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### Percentage of purpose of computer usage among participants at home

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<th>Purpose of Computer Usage</th>
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<th>Study 3</th>
</tr>
</thead>
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<tr>
<td>Educational</td>
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<td>17%</td>
</tr>
<tr>
<td>Watch Programs</td>
<td>37%</td>
<td>24%</td>
<td>38%</td>
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Getting Started with the DiamondTouch Hardware and SDK (Release 2.0)

January 18, 2003 Technology Laboratory Mitsubishi Electric Research Laboratories Copyright © 2003, 2004 Mitsubishi Electric Research Laboratories All Rights Reserved This document is part of the DiamondTouch SDK Documentation.

Before You Start...

- We recommend that, at the very least, you read everything in this document (i.e., everything on this web page, if you're using a web browser to read this).
- If you have never set up and used a DiamondTouch device (or table, as we sometimes refer to them), we recommend that you read about the DiamondTouch Hardware.
- There's also a FAQ that may be of interest.
- You'll need to log in as a user with Administrator privileges to install the device drivers.

System Requirements

Important: Please read carefully.

Operating System

- Microsoft Windows 2000 or later (e.g., Windows XP, Windows Server 2003).
  For Windows 2000 we recommend SP4 or later. (Earlier SPs might work, but we haven't tested with them.)

Computer Hardware

- Uniprocessor without Hyper-Threading Technology
  If your machine is a multiprocessor or a Pentium 4 with Hyper-Threading Technology, or if you're not sure but you think it might be, please see the Release Notes before proceeding.

- USB interface

DiamondTouch Hardware

- DiamondTouch II USB hardware (currently models DT88 and DT107)
  The older DiamondTouch prototypes that require an AC adapter are not supported in Release 2.0.

Setup

For reference, here's a picture of the back of a DT107 with labels for various points of interest.
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Preparation

- Do not plug in the USB cable yet.
- Unzip the DiamondTouch SDK software in a convenient directory (e.g., C:\DiamondTouch). This will create the directory dtsdk2_0 and its contents.
- Place the DiamondTouch device in a convenient location with the white touch surface facing up. The Mitsubishi Electric logo should be on the upper right corner. The device's various connectors (USB, RCA for the conductive pads, etc.) are underneath the device.
- Plug the conductive pads into the RCA jacks on the device, starting with the one closest to the center of the device (which corresponds to the first user, "user 0").
- Do not plug in the USB cable yet.

Device Driver Upgrade

- If you are sure that no drivers for DiamondTouch II USB hardware have ever been installed on your machine, you can proceed to the subsection on Device Driver Installation below. Otherwise continue with the next step.
- Release 2.0 will work only with the device drivers included in Release 2.0. If you have any earlier version of the device driver installed, you must uninstall it and upgrade to the new drivers. See the document Uninstalling DT USB Device Drivers for instructions.
- If you are not sure whether you have any older versions of device drivers for DiamondTouch II USB hardware installed on your machine, see the document Uninstalling DT USB Device Drivers for instructions on how to find out.
- Release 2.0 will not work at all with the device drivers from Release 1.2.

Device Driver Installation

- Assuming you now have no previous version of the DiamondTouch USB device driver installed on your machine you are now ready to install the new drivers.
- You'll need to log in as a user with Administrator privileges (if you haven't already) to install the device drivers. Please do so.
- Now plug the smaller end of the USB cable into the device's USB connector and plug the other end into one of the computer's USB connectors. The following is a typical sequence of events for driver installation.
- Microsoft Windows will pop up the "Welcome to the Found New Hardware Wizard" window. On some machines, this can take a while; don't give up until you've waited at least a minute. In some cases, this window appears below other windows on the screen; look around for it before you decide that it didn't appear.
- Once the wizard window has appeared, follow the prompts. The exact sequence of events may vary between Windows 2000 and Windows XP. Keep in mind that you want to tell the "Found New Hardware Wizard" where to find the drivers. You must specify a location. Don't let it go off and look for them on its own.
- The location of the files is the dtsdk2_0/driver directory. If it lets you specify a particular file, select the file dtloader.inf. Then proceed according to the prompts.
- You should get some indication that the DiamondTouch USB Firmware Loader driver was loaded.
- Now the "Found New Hardware Wizard" window should appear again. This time it wants to load the DiamondTouch USB driver. Follow the prompts as before, except that the specific file for this
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Testing the Installation

- If you have not already done so, plug the smaller end of the USB cable into the DiamondTouch device's USB connector and plug the other end into one of the computer's USB connectors.
- Run merldt (using the executable merldt.exe found in the dtsdk2_0/bin directory).
- merldt will start up in the Table view, which has a black background. To display input from the DiamondTouch device, choose a device identifier from the File menu. (It can take up to ten seconds or so for the operating system and merldt to notice that a DiamondTouch device has been plugged in. If you see no device identifiers in the File menu, make sure the device is plugged in and wait ten seconds or so.) A device identifier looks something like this: DT88-03-07-019. If no device identifiers appear in the File menu, see the TroubleShooting section in the Release Notes. Note that merldt should start displaying input almost instantaneously when you choose the device identifier from the File menu. If it doesn't, there's a problem.
- Please take a moment now to check the device identifier that appears in the File menu. If it has "58" as the two digits after the model designation (i.e., if it looks like DT88-58-26-000 or DT107-58-26-000), your serial number was not properly set at the factory. If that is the case, please do the following:
  - Exit merldt (using the menu item File -> Exit).
  - Make sure that one and only one DiamondTouch device is plugged into the computer.
  - Start up a "Command Prompt" window (usually found in the Microsoft Start menu under Programs).
  - At the command prompt, cd to the dtsdk2_0/bin directory (in your SDK installation).
  - Look under the DiamondTouch device and find the factory label, which is usually near the center of the device.
  - Note the serial number (S/N), which will look something like this: DTII880336001 or like this: DTII1070307019. Note that the first four characters are always "DTII".
  - At the command prompt, give the following command:
    ```
    dtsetid <serial number>
    ``
    - where <serial number> is the serial number you found on the label. For example, if the serial number is DTII1070307019, you would give the command "dtsetid DTII1070307019"
    - When you hit return, dtsetid should indicate that it has successfully updated the serial number. If it fails to update the serial number properly, contact MERL for technical support. (You can see what a successful run of dtsetid looks like here).
    - At this point, the serial number has been updated in the device's on-board non-volatile storage, but it won't be used until the device is started again, so unplug the DiamondTouch device's USB cable, wait ten seconds or so, and plug back in again.
    - Run merldt again and check the device ID in the File menu; it should reflect the new serial number. (If no device ID appears in the File menu, wait ten seconds or so and open the File menu again. If it still does not appear, contact MERL for technical support.)
- Correct operation of the Release 2.0 dtlib depends on the fact that each DiamondTouch device has a unique identifier encoded in the serial number stored in that device. So if the serial number was not properly set at the factory, you should definitely set it according to the procedure above. If you have more than one DiamondTouch device, please check the serial number and set it if necessary, as described above, for each device (one at a time). You only have to do it once for each device.
- Also note that dtsetid causes the DiamondTouch device to write to an on-board EEPROM, which has a limited number of write cycles before it will fail. That number is in the thousands, at least, so there's no problem with setting your serial number, or even with setting it several times if you make mistakes. But you shouldn't run a batch file that does it thousands of times, for example.
- When you select the device identifier, merldt will show the signal-strength values for each antenna as colorful horizontal and vertical bar-graphs on the top and left edges of the display, with the central area showing the bounding box of the area touched by the user(s).
- Here is a screen shot of a typical merldt table view when no one is touching the device. Notice that in this example the signal-strength values are about the same, and are well below the touch strength values for each antenna as colorful horizontal and vertical bar-graphs on the top and left edges of the display, with the central area showing the bounding box of the area touched by the user(s).
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threshold (marked by the horizontal and vertical red lines in the example).

- In general, the signal strength values, when no one is touching the device, should not go much above 50. (Each of the scale divisions represents 50 units; the maximum is 255.) If your Table view shows a much higher variance of signal-strength values, you may be experiencing Radio Frequency Interference (RFI, or "noise").
  - The most likely source of noise problems is a nearby electronic device that produces significant RFI. (We've had RFI problems from an air cleaner, a digital VCR, and camcorders; other possibilities include fluorescent lights, appliances with electric motors, etc.) Move such devices away from the device. Also, some laptops seem to have noise problems, usually when the AC adapter is plugged in. We've had some success with grounding the laptop.
  - You can also try grounding the DiamondTouch device; see the document DiamondTouch Hardware for details.
  - If these measures fail, and if the noise is of low amplitude, there are ways to compensate for the problem.

- Adaptive touch thresholding (a feature of dtlib that is enabled by default in Release 2.0) attempts to compensate for low-amplitude RFI. The current algorithm (a slight improvement on the algorithm of Release 1.2, which was not enabled by default) still has some drawbacks in applications in which the sensitive detection of multiple touches by one user is important.
  - The alternative is to disable adaptive touch thresholding and set the static touch thresholds above the noise level. You can set touch thresholds using the DTSettings utility, or using the merldt utility. (If you run merldt while setting the touch thresholds using DTSettings, you'll need to update the touch thresholds in merldt by using the Set > Reload Device Settings menu command.) See DiamondTouch Settings for more information on touch thresholds and other settings.

- In the merldt Table view, below the table display, there are four lines of text, one for each of the four (potential) users. These lines should look similar to those in the example screen-shot. If you don't see them, try maximizing the merldt window. If your screen resolution is low (e.g., 1024x768) and you have a DT107 device, the text lines may not fit on the display; increase the screen resolution to see the full display.

- When a person who is in contact with a coupling device (such as one of the conductive pads) that is connected to the device touches the device, the text line will display the coordinates of the touched point, and the coordinates of the bounding box of the area touched by the user.

For more information on merldt, see the merldt User's Guide.

Shut Down

- To completely shut down the DiamondTouch device, first exit merldt (using the menu item File -> Exit)

- If there is an "Unplug or Eject Hardware" icon in the system tray (it has a green arrow), then use it to stop the DiamondTouch hardware; if not, proceed to the next step.

- Unplug the USB cable.
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DTFlash Application Development [rev. 1.045]

[Note: You must enable Javascript when viewing this page to see all of the generated property, method and event information.]

DTFlash applications are Flash applications

DTFlash is a framework for writing DiamondTouch multi-user multi-touch touch table applications. It consists mainly of an API written in Flash ActionScript 2.0 that allows DiamondTouch applications to be created with Adobe Flash. Therefore, a DTFlash application is a Flash application (.swf file) that is created using some ActionScript 2.0 class files (.as files) contained under the com/merl/diamondTouch path.

The DTFlash framework consists of a DTFlash application and a container program. This container (typically the Internet Explorer web browser or a custom Windows program) hosts both the Flash ActiveX control and the DiamondTouch ActiveX control. The container program is responsible for receiving touch events from the DiamondTouch ActiveX control and, after re-formatting them, forwarding them to the DTFlash application hosted by the Flash ActiveX control. Example code to do this in DHTML as well as in C# is provided. This mechanism assumes that the Flash program has a reference called dt to the DiamondTouch class at the _root level. (ie "import com.merl.diamondTouch.*; var dt:DiamondTouch = DiamondTouch.getDiamondTouch(); ").

You can test your new DTFlash (.swf) application using the supplied DTFlash.exe utility.

The most simple way to quickly develop and test a DTFlash application is to use the provided DTFlash.exe program to handle the tasks of the container mentioned above. Source code for the DTFlash container executable is provided in C# and .NET 1.1, which can be imported to later .NET development environments. DTFlash.exe reads a few configuration tags from a local config.xml file. Simply set the FlashFilename tag to your .swf file (e.g. touchable_shapes.swf) and execute DTFlash.exe.

```
<?xml version="1.0" standalone="yes" ?>
<DTFlash>
  <FlashFilename>grayball.swf</FlashFilename>
  <Maximized>false</Maximized>
  <FullScreen>false</FullScreen>
  <ShowBrowseButton>false</ShowBrowseButton>
  <ShowStatusBar>false</ShowStatusBar>
  <ShowTouchDataInTitleBar>false</ShowTouchDataInTitleBar>
  <EnableSegments>false</EnableSegments>
  <EnableSignals>false</EnableSignals>
  <ProcessPriority>AboveNormal</ProcessPriority>
  <FlashMovieWidth>900</FlashMovieWidth>
  <FlashMovieHeight>700</FlashMovieHeight>
  <PromptForUserRotations>false</PromptForUserRotations>
  <RotateUser0>0</RotateUser0>
  <RotateUser1>90</RotateUser1>
  <RotateUser2>180</RotateUser2>
  <RotateUser3>270</RotateUser3>
</DTFlash>
```

Note that your .swf file should be in the same directory as the DTFlash.exe executable (which itself relies on some DLLs and ActiveX controls, also found in the same directory). DTFlash uses a custom DiamondTouch ActiveX control, so it only works on Microsoft Windows systems. (Technically, it is the container program mentioned above that uses the ActiveX control and has this reliance.) Run register_DiamondTouchEx_activeX_control.bat to register the provided DiamondTouch ActiveX control with your computer. (The DiamondTouch installer may have already done this for you, but it doesn't hurt to do it again.) To develop new DTFlash applications, you'll need the supplied "com" directory to be in the same directory as your Flash .fla source file(s), or just point to it via the Classpath.
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Some samples are provided with web page code (a .htm file) that allows the .swf file to be tested directly in Internet Explorer rather than using DTFlash.exe. Two things to keep in mind are that you still need to register the DiamondTouchEx ActiveX control, and default browser security options are such that it is easier to run this web page through a web server rather than the file system. That is, browse to the supplied .htm file with a http://localhost URL rather than double clicking on the file name in Windows Explorer. (You have to have some kind of web server running on localhost for this to work)

Any MovieClip object can be made touchable. Touchable objects receive special touch events, and can be manipulated simultaneously while another toucher is manipulating a different touchable object concurrently.

DTFlash is designed such that anything that is a MovieClip can be registered to receive touch events. Non-MovieClip objects can be wrapped inside a MovieClip. The DTF Flash API is written such that it should be familiar for Flash programmers. For example, where Flash MovieClip objects have onMouseDown, onMouseMove, and onMouseUp events, DTF Flash provides onToucherDown, onToucherMove, and onToucherUp events. All DTF Flash events have two arguments. The first argument, Sender, is a reference to the object which generated the call to the event handler. The second argument, dtev, is a TouchEventData object containing touch data for a specific touch event. It includes fields such as receiver, action (1=touch down, 2=touch move, 3=touch up), ulx, uly, lrx, lry (the upper left and lower right x & y coordinates of the bounding box containing the touch that was detected by the toucher indicated by the receiver argument; where the receiver typically has a value from 0 to 3). Some convenience functions have been added to facilitate common operations (eg startToucherDrag(), which is similar to the Flash startDrag() method). More details below, after a simple example.

Step by Step Instructions for Creating and Running a Simple Touch Application

These instructions step you through the tasks of creating a simple DTF Flash application consisting of two circles that can be dragged concurrently by two different touchers.

If DiamondTouch has not been installed on your system, yet, then run the DiamondTouch installer to install the DiamondTouch table drivers. Plug in the DiamondTouch USB cable and point it to the drivers in C:\Program Files\MERL\DiamondTouch SDK 2.1\driver directory (or similar) if prompted.

Start the Flash authoring tool and create a new Flash Document. Create a gray circle. Right click on the gray circle and select "Convert to Symbol..." to convert it to a Movie clip with its registration point set to the center of the object. Check the "Export for ActionScript" checkbox.

In the same way, on the same layer, create another circle, this time using the color orange. Convert it to a MovieClip called orangeball_mc.

Create a new layer called scripts and, with the first frame of this new layer selected, paste the following ActionScript code into the Actions window in the Flash authoring tool:

```actionscript
//=================== Code Example for a draggable widget ===========================
import com.merl.diamondTouch.*;
var dt:DiamondTouch = DiamondTouch.getDiamondTouch();
dt.enableTouchEmulation(); // DEBUG Simulate touches via a mouse
dt.showCursorAndTouchBox(true); // DEBUG

dt.addObserver(grayball_mc);
grayball_mc.onToucherPress = function(sender:Object, dtev:TouchEventData) {
  dt.startToucherDrag(this, dtev, false);
};
grayball_mc.onToucherRelease = function(sender:Object, dtev:TouchEventData) {
  dt.stopToucherDrag(this, dtev);
};
grayball_mc.onToucherReleaseOutside = grayball_mc.onToucherRelease;
dt.addObserver(orangeball_mc);
orangeball_mc.onToucherPress = grayball_mc.onToucherPress;
orangeball_mc.onToucherRelease = grayball_mc.onToucherRelease;
orangeball_mc.onToucherReleaseOutside = grayball_mc.onToucherReleaseOutside;

Execute the menu item "File > Save as...", browse to the directory that contains the com subdirectory and save as touchable_shapes.fla.
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Create touchable_shapes.swf by executing "File > Publish".

Now test this with the supplied DTFlash.exe wrapper program (requires .NET 1.1 or that you recompile the supplied DTFlash Visual Studio solution under .NET 2.0 or later). Manually copy touchable_shapes.swf to the directory containing DTFlash.exe. Edit the config.xml in that directory so that the FlashFilename tag is set to touchable_shapes.swf. Execute DTFlash.exe and use your finger on the DiamondTouch table to drag one of the balls around. Note that a second toucher can simultaneously drag the other ball around.

DTFlash Touch Events

DTFlash supports many touch events. The startToucherDrag() and stopToucherDrag() methods used above are supplied with the framework (like the Flash startDrag() and stopDrag() methods). These methods supply internal handlers for onToucherDown, onToucherMove, and onToucherUp events. If you want your touchable objects to have more functionality than simple dragging, then you should implement your own touch event handler routines rather than calling startToucherDrag()/stopToucherDrag().

DTFlash supports a variety of touch events (see the section on DiamondTouch events for more info):

======================================== Touch Events =========================================

Primitive Events:
- onToucherEvent, onToucherDown, onToucherMove, onToucherUp,
- onToucherSegmentCountChanged

Enhanced Primitives:
- onToucherPress, onToucherRelease, onToucherReleaseOutside,
- onToucherTap, onToucherDoubleTap, onToucherTripleTap, onToucherQuadrupleTap,
- onToucherHover, onToucherDragOut, onToucherDragOver, onToucherRollOver,
- onToucherRollOut

Semantic Operations:
- startToucherDrag, stopToucherDrag

For simple applications, rather than writing your own onToucherXXX handlers you can simply use pre-defined "behaviors" (AS2.0 classes). These can be applied to an existing MovieClip. Simply set the "AS 2.0 Class" in the Symbol Properties for the MovieClip to one of these:

======================================== Behaviors =========================================

com.merl.diamondTouch.behaviors.DraggableThing
com.merl.diamondTouch.behaviors.RotatableThing

Since these behaviors define their own touch event handlers (such as onToucherDown, etc), don't overwrite them with your own definitions. Except for very simple applications, it's probably better to write your own touch handlers, as shown earlier. Also note that these behaviors require that the registration point for the associated MovieClip be in the center of the clip. When using these behavior classes, you should still instantiate the DiamondTouch object at the _root level in your initialization code:

import com.merl.diamondTouch.*;
var dt:DiamondTouch = DiamondTouch.getDiamondTouch()