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].

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 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 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 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).

Fantasy play increases steadily during the following years. At the age of 4, children can create and combine ideas, coordinate roles and understand complex stories [11]. 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 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. SAM [18] 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 ladybirds 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.

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 are 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 collaborative play (see previous section).

The development of the Fantasy Table follows a timeline of almost 2 years of analysis, prototyping and formal and informal evaluations with major stakeholders [7]. The analysis phase augmented the literature review with observations at a university nursery to understand the spontaneous play behaviour of pre-school children within the UK Early Years curriculum (3-5). Interviews and focus groups were run with staff members and teachers at different nurseries. The prototyping phase was facilitated by the involvement of a group of children of different ages (2-8 years old).

Several hardware devices were considered at the early stages with the aim of selecting an option which (a) could support group
interaction; (b) could accommodate smaller people and the
behavioural unpredictability typical of young children; (c) could
be available in state schools in the near future and; (d) could be
transported and assembled for in situ testing. The early
discussions concentrated on interactive tabletops and interactive
whiteboards. A tabletop solution was preferred as it fits well
within the typical routine of UK nurseries were a variety of toys
and props are prepared in the morning on different tables by the
teacher to allow children a wide variety of contexts to experiment
with. The MERL DiamondTouch (DT) tabletop [6] 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.

A robust iron frame (as indicated in Figure 1) was built to hold
the DT and allow the projector to be mounted at a height that
made it difficult for the children to touch it (122cm from the table
to the projector). The frame was secured to a coffee table by
several straps. The coffee table was 45 cm height, which meant
that the children could reach all the corners of the tabletop surface
whilst seated.

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 (‘gaagaagaaugaa’ 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.

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 (2½ - 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.

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.

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.

Using the area grid coding scheme, the type of object moved and their initial and final positions were recorded alongside the start and end time of each movement and other important contextual details. The total number of objects moved from their starting positions in the two environments was also counted (moved objects), alongside the number of objects moved from their original position and placed onto the tree house or moved within the tree house (engaged objects). An independent evaluator double-coded 11% of the videos. The inter-rater reliability was 97%.

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

Figure 7: Area grid coding scheme
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. Only language allows ambiguous identification of the children’s denotive 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 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.

### 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>

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.

Ben : (boy, 3 ½ yrs) and Joe (boy, 3 ½ yrs) play together with the real 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)

Verbalisation was more frequent in the physical than 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: 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: *Wisshhh* (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 – dolls, sticks, and stone - with vocalisations)*.

Tom: *Bush, bush. I’m the stone adventure!*  
Jack: *Blowwww.. blowwww..* *(Continue playing in silence for a while)* *I got stone with the stick.*

Tom: *Bush… Bush! (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)*

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 extract 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: *(Drags the TV) Aaahhh! *(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: *(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. (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>Moving actions</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>
<td>7</td>
<td>1%</td>
</tr>
<tr>
<td>Failed movement</td>
<td>19</td>
<td>4%</td>
</tr>
<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>Fantasy play characteristics</th>
<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>
<td>0.5</td>
</tr>
<tr>
<td>Session 2</td>
<td>1.3</td>
<td>0.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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 (girl, 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 girl by using the magic wand)

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.
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