Augmenting Imagination for Children with Autism

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ABSTRACT
Evidence shows that children with autism suffer a deficit in spontaneous pretend play, which is believed to have developmental links to key competences of their future lives such as creativity and social interaction. In my PhD thesis, I would like to examine the use of Augmented Reality (AR), which superimposes imaginary objects on the real scene, as a novel therapeutic approach that may encourage children with autism to be involved in pretend play. In this paper, we present the design of an interactive AR system as an entry point to explore the main research questions of the thesis.

Categories and Subject Descriptors
H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities.

General Terms
Design, Experimentation, Human Factors.

Keywords
Augmented Reality, autism, pretend play, social interaction.

1. INTRODUCTION
Difficulty in sharing imaginative play (often referred to as pretend or symbolic play) is one diagnostic criterion of reduced social interaction in Autism Spectrum Disorder [1]. Pretend play has attracted wide attention by researchers of early childhood development. It is believed that pretend play has developmental links to creativity and social interaction [4].

Among various definitions of pretend play in developmental literature, three fundamental forms - characterised by Leslie [10] - are well established in the study of autism: (1)object substitution; (2)attribution of absent/false properties; (3)presence of imaginary objects. One well recognized finding is that children with autism have severely impaired response to spontaneous pretend play, compared to both neurotypical and very low IQ children. They are, however, able to perform some pretend play under elicited or instructed circumstances [8]. Behavioral interventions such as modeling and systematic prompting have demonstrated improvements in pretend play of children with autism.

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There remain several challenges in improving pretend play. Forming the intention that underlies pretend-style motions is suggested as a key component in the inner motivated nature of play. One major concern is that the child might simply imitate the modeled behaviors, without actually forming an intention of play activity as normal children do [11]. Another challenge is that one-on-one teaching is often costly, as is follow-up maintenance training. Convenient intervention centers may also not be available, especially in sparsely populated or less developed areas. These practical problems motivate researchers from different disciplines to seek alternative therapeutic approaches.

The concept of Augmented Reality is to extend the physical world with digital information that is registered in three-dimensions and interactive in real-time [2]. AR systems have been used in various areas such as military, medicine, maintenance and industry. As the development of computer vision technologies and hardware capacities (e.g. sensor, display, processor), emerging AR applications become accessible on personal devices. The core approach of my thesis proposal is to create enriched pretend play scenes by extending the physical environment with augmented contents. Those contents are registered and rendered in meaningful ways in order to illustrate the intention of pretense and elicit pretend play behaviors. Figure 1 demonstrates a simple scene of pretending a wooden block as a car and a shoe box as a garage.

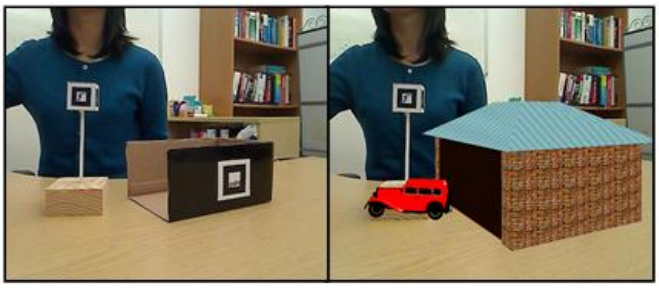


Figure 1 Concept demonstration: Left: in reality there is a wooden block and a shoe box. Right: In the AR environment, the user sees a car and a garage on the table.

We identify two main reasons why Augmented Reality technologies may assist children with autism to establish improved self-motivation in promoting pretend play and social interaction. First, Augmented Reality supports visual conceptualisation of various forms of pretend play by superimposing virtual contents onto the physical world with which the children with autism are familiar. We expect this to reduce pure imitation of pretend-style motions. Second, AR technologies may offer extended and alternative opportunities beyond professional therapeutic contexts, allowing family members and typical developed peers to be actively involved in

helping autistic children to carry out pretend play and increase their social contact in a play environment.

2. Research Goals and Contributions

I would like to examine the potential for Augmented Reality technologies to promote spontaneous responses of children with autism in both solitary and sociodramatic pretend play. There are three research goals identified in the proposal:

(1) Elicit the proper conceptualization of pretense during pretend play with the advance of AR technologies

(2) Encourage divergent forms of pretend play under a structured environment

(3) Promote sharing of imaginative play while avoiding potential obstacles such as impaired or delayed language skills.

By achieving these research goals, we expect to make two main contributions as below, which benefit researchers and practitioners from communities such as AR, interaction design for children and general HCI.

(1) Advance our knowledge of the potential of AR technologies in promoting pretend play and social interaction behaviours of children with autism.

(2) Identify usability and interaction challenges of young children (both neurotypical and autistic) within an AR environment and provide related design guidelines.

3. Method

Although AR technologies have demonstrated positive impact with cognitive and psychological related therapies [9][13], the effect of enhancing pretend play skills, in particular for children with autism, hasn't been explored by other researchers in the previous literature. As a starting point, we would like to examine the positive impact of AR technologies in solitary pretend play scenarios. In contrast to the simple behavior modeling therapies, we aim to design an AR system that can dynamically overlay imaginary contents on the real object/scene, which enrich the representation of the intention of pretense beside verbal indications. Imaginary contents cover all three forms of pretense according to Leslie's definition as illustrated in the following example: (1) object substitution: to pretend a block is a car, a virtual car will be rendered on the block (Figure 1); (2) absent property: anthropomorphize a doll by adding speech and action; (3) imaginary object: the child pretends to make a phone call using a virtual phone. In the following sections, we will describe the detailed design of play scenarios and the proposed AR system.

3.1 Play Scenario Design

After developing the fundamental concept and scope of using AR technologies to help promote pretend play behaviors, we have to decide what play scenarios the prototype AR system will support. Due to the arbitrary nature of play, the selection of representative play scenarios becomes very demanding. To begin with, we went through previous literatures regarding pretend play research and intervention with autistic children. We referred to the play scenarios and play materials used in their controlled experiments and transferred verbal instructions given by the experimenter or teacher to visual AR contents. As a result, the representations of pretense are constantly visible to the child, which provide an alternative chance to increase his or her comprehension and engagement during play.

On the other hand, it is suggested that as children are gradually capable to separate the action and the objects that the action is directed to, their use of object becomes less egocentric [12][15]. Therefore we decided to adopt a progression of symbolic play enhancement, beginning with object and self-directed play, gradually approaching doll-directed play. Taking the object substitution scenario as an example, with the object-directed scenario, the child pretends small pieces of sponge cubes are food and "cooks" them in a toy tray; with the self-directed scenario, the child puts the sponge cubes towards his mouth as if he is eating them; with the doll-directed scenario, the child puts the sponge cubes close to the doll's mouth pretending to feed it.

We developed a framework of pretend play scenarios in two dimensions: action direction and the form of pretense. A sample set of proposed pretend play scenarios is shown in Table 1.

Table 1 Play scenarios design

Pretense / Action Direction	Object Substitution	Absent/False Property	Imaginary Object
Object-directed	Car, garage, airplane, train	-	Exhaust, virtual plane, bridge
Self-directed	Tooth brush, umbrella, bubble wand, telephone, doctor props	I am a driver, I am a doctor, rainy weather	Tooth brush, umbrella, bubble wand, telephone, wheel, doctor props
Doll-directed	Feed (food, drink), toothbrush, bed	"(doll) I'm hungry/thirsty" "(doll) I want to go to bed"	Feed (food, drink), toothbrush

The majority of pretense scenarios described above are referred to by materials and methods used in previous literature, with a few exceptions which are more feasible with the advance of AR technologies. Such scenarios usually involve absent/false properties (e.g. rainy) and imaginary objects (e.g. exhaust, airplane, steering wheel) which provide visual cues of the pretense context, instead of a pure verbal description given by the instructors or teachers. In addition, we realized that in doll-directed scenarios context information is especially important in suggesting possible actions. To provide such a social context, instead of going through individual scenes, we decided to present a sequence of related scenes involving both doll and self-directed actions to make a complete story: (1) make a phone call to Sara (the doll); (2) drive Sara home; (3) feed Sara at home; (4) play doctor with Sara; (5) put Sara to bed.

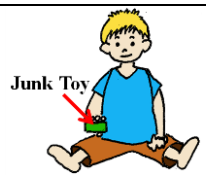
The purpose of the initial play scenario set is to provide a compact selection of play scenarios that covers the majority of the elemental forms of pretense in play. Once it is demonstrated that AR technologies play a positive impact in supporting pretend play of children with autism, more play scenarios could be conceived by taking the practical play scenarios from school or home repertoire into consideration. In addition, we may further refine the system to enable customizing and authoring new scenarios by adults and even children themselves. Thus, the AR system becomes an open framework that supports users to dynamically create pretend play activities, which we expect to be favorable to

encourage the production and sharing of imaginative play for children with autism.

3.2 AR System Design

In this section we describe the design of the AR system in detail. The system consists of three main parts: physical contents, virtual contents and display. Virtual contents are registered in the physical scene via the display. Table 2 gives an example of the AR environment regarding four types of physical contents: junk toy, user, environment and doll.

Table 2 AR environment component illustration

Physical Contents	Virtual Contents	Display (what user sees)
	 (airplane)	
	 (doctor props)	
	 (rainy)	
	 (speech bubble)	

3.2.1 *Junk Toys*

A bunch of tangible junk toys (which are used to "denote vague or nonfunctional objects that children [use] in play" [3], e.g. a piece of wood block, a tube or a rod) are used in the system with two main reasons: (1) junk toys are prevalent materials involved in empirical experiments in previous research on pretend play with autism. Since junk toys are not bound with explicit usage, they are favorable to free children's potential to assign creative symbolic interpretation to them; (2) junk toys, as tangible objects, both enable children to interact with the system in a direct manner and provide immediate haptic feedback during the interaction. The latter advantage may further augment specific pretense experiences to object substitution.

With regard to promoting divergent pretend behavior, the system provides multiple pretense options for each scenario. One can pretend a block is a car, airplane, telephone, toothbrush or bubble wand and a doll can be thirsty, sick or sleepy. We hope by interacting with a system that combines the real and the imaginary, autistic children's generative ability of spontaneous pretend play will improve. The potential benefits include reduced repetitive play behaviors and enhanced inner play motivation. One interesting design issue is to enable young children to dynamically associate various physical objects with different imaginary objects, while the system is able to respond to such dynamic coupling/decoupling in a meaningful way.

3.2.2 *Tracking*

We use marker-based instead of model-based tracking as a starting point. The reasons are: (1) the way the child manipulates an object in his/her hand is arbitrary. A model-based approach can track the position and orientation status of the object. Nevertheless, the common used edge-based model tracking is not robust with fast motion, and once failed, it is complex to recover; (2) marker tracking is more robust as long as it is visible to the camera. It can be installed around the object to reduce hand occlusion. The downside is that extra marker installation might affect the way in which a child holds the object and distract his/her attention away from the object itself to the marker. These ergonomic and cognitive issues should be carefully considered when designing the prototype. In addition, other tracking method(s) (e.g. electromagnetic tracker) might be used to compensate the intermittent failure of optical tracking under occlusion and fast movement.

3.2.3 *Interaction Setup*

There are two potential interaction setups considering the two-dimension play scenario set. Figure 2 illustrates the two setups seen from the side.

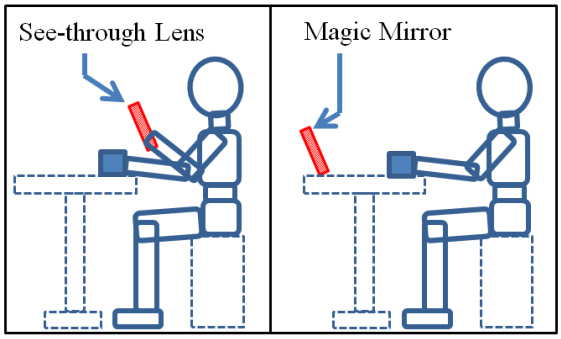


Figure 2 Interaction setups. Left: screen as a see-through lens; Right: screen as a magic mirror

With the one on the left side, the screen functions as a see-through lens between the user and the junk toy. It provides a direct view of the virtual contents augmented onto the real scene while it either requires the child to constantly hold the device with one hand or have it fixed somehow with a fixture. In the setup on the right side, the screen functions as a magic mirror, in front of which the child will perform pretend play. The display provides an indirect mirrored view comparing with the first setup. The advance of the second setup is that it frees both hands of the user to interact with the augmented environment. Moreover, it supports consistent viewing angles for both object/doll-directed and self-direct pretend play while with the former one, a switch between a rear view and frontal view is required which might be problematic in scenarios that involve both object/doll-directed and self-directed actions, e.g. pretending to be a doctor and give a body examination to a doll. Although the effect difference in conceptualizing the intention of pretense remains unknown

between the two physical setups, considering the flexibility in supporting self-directed play and bimanual manipulation, we would like to develop the prototype system with the second interaction setup, in which the display functions as an augmented mirror.

4. Work-In-Progress and Future Plan

We are currently developing the first prototype which implements fundamental object-directed scenarios using marker-based tracking. A full user scenario includes the following steps: (1) a set of prepared junk toys with markers attached are presented on the table between the user and the display; (2) the program asks the child to choose which object (car, airplane or train) he or she wants to pretend the wooden brick to be; (3) the child selects one option and corresponding AR contents are rendered on the real scene through the display; (4) after the play finishes, the program goes back to step (2) and asks the child to start a new play scenario. The loop continues until the child decides to stop. Due to the extra setup of physical objects for the AR system and to make the autistic children feel comfortable within the unfamiliar situation, an adult that the child is familiar with is preferred to facilitate him or her to play properly and switch between different scenarios.

In the next stage, we would like to conduct a series of usability studies, firstly with adult and typical developed preschool children to evaluate the robustness and scenario design of the system, and then with preschool autistic children to evaluate the positive effect including spontaneous response and play divergence. Based on the study results, we will refine the system and continue implementing self and doll-directed scenarios. Further usability studies will be conducted.

5. Related Work

Several attempts have been made to apply advanced computer technologies such as tangible interfaces and virtual reality (VR) to improve play behaviors. Farr [5] and his colleagues built a knight castle toy augmented with audio feedback, which inspired cooperative play in a natural play environment. They conducted another experiment [6] comparing Topobo (tangible construction toy) and Lego, which showed that Topobo elicited more social interaction. A VR system was built by Herrera [7] and colleagues to improve the ability of children with autism to comprehend imaginary transformations. The results showed positive effects in two case studies, although the capacity of VR to help the children generalize what they learn in the virtual world to the physical world remains unknown. Tartaro and Cassell [14] developed an authorable life-sized virtual peer agent to interact with autistic child during a storytelling scenario via speech and gesture. The system was proposed as a new way to help children with autism to learn communication and social reciprocation skills.

There has been relatively little research into potential applications of AR in pretend play for autistic children. However, preliminary results have shown positive adoption and beneficial effects of AR technologies in general cognitive rehabilitation [13] and psychological disorder treatment [9]. We are, therefore, keen to explore new opportunities brought by AR to stimulate pretend play of children with autism, from both cognitive and social development perspectives.

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