Can We Augment Reality with "Mental Images" to Elicit Pretend Play? A Usability Study

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Abstract
Pretend play is a symbolic activity in one's childhood which develops critical competences such as mental representation, linguistic expression and social knowledge. However, children with autism spectrum condition (ASC) are often found lacking in pretend play. Inspired by the analogy between pretend play and Augmented Reality (AR), both of which require dual representations of reality and its symbolic counterpart, we designed an AR system that aims to assist young children with ASC to be engaged in open-ended pretend play by overlaying suggested imaginary "mental images" over the physical environment. A usability study with normally developed children aged 4 to 5 was conducted to inform a future empirical study with autistic children.

Author Keywords
Augmented Reality; pretend play; mental image; autism; children

ACM Classification Keywords
H.5.1 Multimedia Information Systems

General Terms
Design, Human Factors

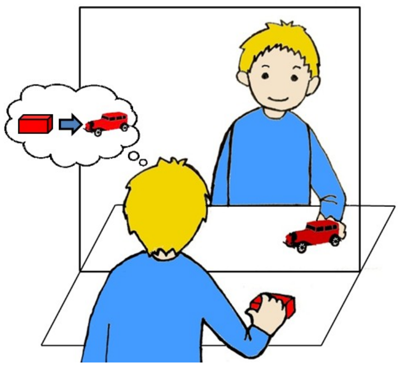


Figure 1: An example of object substitution with AR. In reality the child holds a block in his hand. In the AR display, an imaginary car overlays on the block.

Introduction

Emerging in the second year of life, pretend play requires interpreting objects and actions in a symbolic manner. It is considered to be a critical facilitator of cognition, language and social development in childhood [3]. Leslie divided pretend play into three forms [9]: (1) object substitution (e.g. use a banana as a telephone); (2) attribution of absent/false properties (e.g. pretend the toy oven is hot); (3) presence of imaginary objects (e.g. hold an imaginary toothbrush).

A significant body of research finds that children with ASC show impoverished spontaneous pretend play compared to both neurotypical and mentally challenged children [8]. It is also suggested that children with ASC can produce some pretend-like actions under more structured circumstances, but have difficulty in creating flexible and novel play ideas [7]. While the causes remain inconclusive, some major theories include impairments or delayed developments in the mechanics of pretense, executive dysfunction and lack of incentive due to literal thinking [8].

Developmental psychologists note that pretend play relies on dual representations of reality and pretense. For example, Piaget argued that the mental image of an absent object assimilated to a present object is evoked during pretend play [10]. Meanwhile, AR combines real and virtual by overlaying virtual content on the real world. It naturally assists visualizing the intention of pretense in reality, without which it can only be interpreted by an observer indirectly based on the observed actions. As Figure 1 illustrates, AR enables the child to see a suggested "mental image" of an imaginary car projected on a real block held in his hand. He can then explore play ideas without any explicit verbal instruction (e.g. let's park the car in the garage) or actions demonstrated by the adult. There are several potential advantages of the AR approach: (1) evoke the mental imagery of pretense by showing external representation of object substitution to individuals with ASC, who are often described as visual thinkers [5]; (2) encourage children to explore possible play ideas by direct manipulation of suggested pretense imagery and reflect symbolic representation of objects via the embodied play experience; (3) instead of being told or shown what to pretend, the AR system leaves sufficient space for children to develop and carry out pretense ideas on their own.

In this paper, we present the design and implementation of an AR system to investigate the potential of AR as a specific external representation to stimulate internal mental imagery and play activities involving pretense. Usability study results with normally developed children are discussed. Our work provides insights of using developmental psychology literature to guide the design and evaluation of the AR system. Special considerations to enhance usability of the AR system to young children with limited cognitive and motor abilities are addressed.

Related work

There is a rich research corpus regarding pretend play of both neurotypical and autistic children in the developmental psychology literature. Very few studies, however, address the design of computer-assisted systems to enhance early forms of pretend play, which are the foundation of social pretend play in later childhood. Based on research on imagination and ASC, Herrera [6] and colleagues designed a Virtual Reality (VR) system to teach object recognition and usage for a

	Car	Train	Plane
Blk1	Car	Train	Airplane
Blk2	School bus	Coach	Helicopter
Blk3	Petrol pump	Traffic light	Stairs vehicle
Box	School	Station	Hangar
Add1	Bridge	Rail	Runway
Add2	Dusty	Crane	Fire

Table 1. A summary of virtual objects in three vehicle scenes. Different virtual objects are registered on blocks (Blk1-3) and a box (Box) in each scene. Additional virtual objects/effects (Add1-2) are dynamically registered in the AR

supermarket shopping task for children with ASC, while symbolic transformation of objects is demonstrated in an embedded video format. An increase in symbolic understanding was reported in both pre/post testing and surveys from parents and educational professionals. In spite of a small sample size (N=2), their work has shed light on using psychological theories to inform the design and evaluation of computer systems in teaching imaginative thinking to autistic children. In addition, we believe the physical disconnection of a VR system can be largely mitigated by AR technologies, where children can make better sense of pretense through embodied activities.

We are not aware of any AR system with a specific focus to elicit pretend play of young children, but AR systems for children with special needs have recently drawn intense research attention [4][12]. In particular, Radu et al. [11] reviewed AR usability issues raised by special developmental capacities of young children. We hope that our study can extend such knowledge to autistic children, whose cognitive abilities are potentially further restricted.

Method

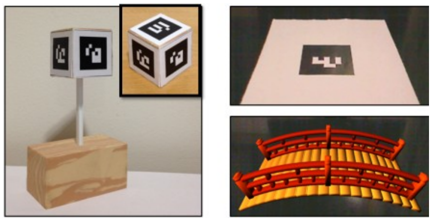
In this section, we present an AR system that aims to encourage pretend play for young children with ASC. We illustrate the design of an experiment that compares pretend play behaviours between the AR system and an equivalent non-computer setup.

System design

Our AR system functions as a magic display with a mirrored view that shows imaginary elements in the reflected reality (as shown in Figure 1). The mirror metaphor is chosen for several reasons: (1) children are familiar with watching themselves in the mirror; (2) they do not have to wear any extra equipment (e.g. Head-Mounted Display) or hold any device (e.g. a mobile phone) to see the augmentation; (3) it allows bimanual manipulation which is essential in a play scenario; (4) it provides a consistent shared view for multiple users.

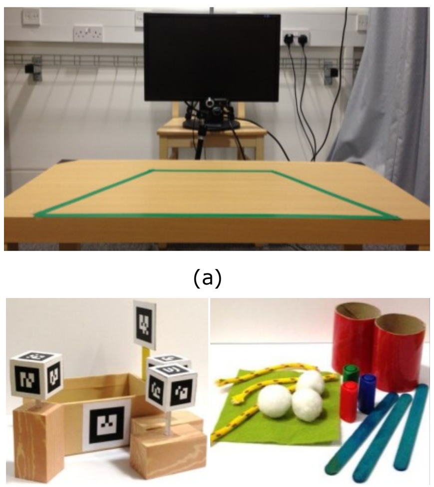
Autistic children often show obsessive interest in machinery such as vehicles [2], leading us to choose vehicles as the play theme and to develop three independent scenes including cars, trains and airplanes. We carefully select augmentations to elicit pretense behaviours in three tiers: (1) basic actions towards the substituted object (e.g. push the “train” along the table) (2) appropriate actions under situation-related cues (e.g. push the “train” into the “train station”) (3) novel pretense actions using non-augmented physical props (e.g. put pen tops on the “train” as “drivers”). Table 1 shows a summary of related augmentations.

Behaviour of the first type indicates the spontaneity of children’s engagement in pretend play with the AR system. Special visual stimuli are involved such as rotation of car/train wheels and helicopter propellers. Behaviour of the second type is expected as a result of the production of flexible play ideas in response to vehicle related cues such as a bridge, railway track or runway. Behaviour of the third type is designed to encourage pretense with non-AR physical props. This is done by creating situations that are well suited for non-augmented props. One example is to reveal a fire effect on the table in the airplane theme in order to encourage the child to carry out rescue-related play with the rescue helicopter and using non-AR props as people to be rescued. Those non-AR props include junk



(a) (b)

Figure 2: Marker-based tracking:
(a) the marker cube attached to a block
(b) the registration to the calibration marker



(a) (b) (c)

Figure 3: Experiment apparatus of the AR condition:
(a) monitor, webcam and table
(b) blocks and box with markers
(c) non-AR props

objects with various shapes that are found in daily life without specific functions (e.g. a piece of cloth, popsicle stick, paper roll, etc.). They are frequently used in psychology experiments relating to pretend play. They are meant to encourage object substitution, because it is easier for children to inhibit the object's original function when substituting it as something else.

System implementation

The system is implemented using a locally modified version of Goblin XNA open source [13] and the ALVAR tracking library [14]. We use marker-based tracking in preference to other computer vision-based tracking methods for two reasons: (1) it allows a flexible range of trackable objects compared with model-based tracking which requires matched 3D models of each object beforehand; (2) hand occlusion can be largely avoided by installing the marker displaced from the target object. Figure 2(a) shows the installation of markers on one of the foam blocks. The system detects the marker with the biggest area among those associated to the same virtual object. The double exponential smoothing method is used to reduce jitter.

For theme-related virtual objects such as the bridge, railway and runway which are meant for the vehicle to move over, occlusion is unavoidable if we simply register them with a 2D marker placed on the table. Instead, prior to the experiment we put a calibration marker in the middle of the table and record its transformation matrix, and then remove it while still registering those virtual objects at the calibration marker (Figure 2(b)).

Experiment design

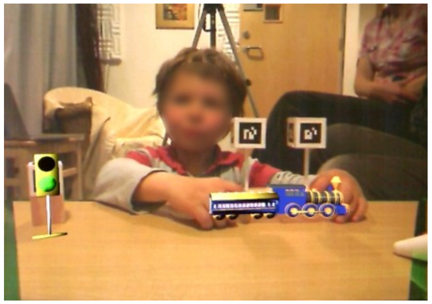
We designed a between-subject experiment to examine the effect of using the AR system to promote pretend play for high functioning autistic children with the minimum adult elicitation, in comparison to a non-AR setup. The design of the experiment is largely informed by literature in psychology and we have adopted several improvements during the usability study.

Apparatus

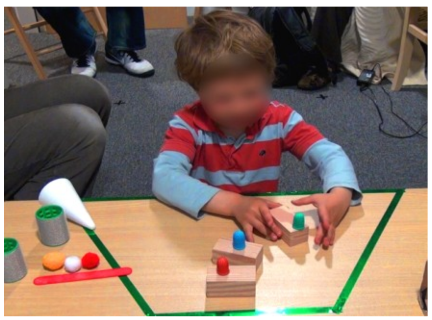
The setup of the AR condition is shown in Figure 3. It contains a 24-inch monitor, a Logitech webcam, a table (45*90*45cm), three foam blocks (3.5*3.5*7cm) and a cardboard box (6*9*14cm) with markers attached and a set of non-AR props. The non-AR setup contains the same table and non-AR props, plus blocks and a box of the same size but without marker. The monitor is switched off in the non-AR condition. In addition, we labeled a trapezoidal area on the table to emphasize the range of the camera view. In both conditions we asked the participant to play within this area.

Procedure

The order of the AR and non-AR sessions is counterbalanced among subjects. In each session, there are three tasks and the order is randomized. Each task lasts at least five minutes. Both sessions share the same procedure: (1) a brief introduction; (2) the experimenter holds one block and asks: "*show me how you can play with this block as a car/train/airplane. You can use anything you like on the table in your play*", then gives the block to the participant to carry out play; (3) the experimenter should encourage the child to carry on with play when necessary by saying: "*I want to see more how you can play with the block as a car/ train/airplane. Let's try some more*"; (4) after 5



(a)



(b)

Figure 4: Usability study snapshot
(a) AR condition train theme
(b) non-AR condition train theme

minutes, the experimenter says: "*Very good. Now let's stop and put everything back*", initializes the materials and starts the next task. There is a short break between the two sessions.

Data collection and coding
There are four sources of data collection for the experiment: (1) video record; (2) parent questionnaire and interview (participant basic information, engagement rating and additional questions); (3) participant questionnaire (fun and preference of the two sessions); (4) participant screening: Childhood Autism Rating Scale, 2nd edition (CARS2) and British Picture Vocabulary Scale: 3rd edition (BPVS3). We label discrete actions in the video in three categories [7]: (1) pretend play; (2) relational play; (3) simple manipulation. Play behaviors that reflect any of the three forms of pretense defined by Leslie [9] will be counted as pretend play, whether reality or fantasy related. One example is that in both non-AR and AR conditions, if the child pushes a block along the table and makes the sound of a car, it will be counted as pretend play. In both conditions the child manipulates an imaginary car. In the non-AR condition, the imaginary car replaces the block only in the child's mind, while in the AR condition the replacement is visible. In addition, due to the nature of pretense, we further use two levels to indicate the certainty of the pretend play [1]: quite sure or ambiguous.

Usability Study
Four neurotypical children took part in the usability study (two male and two female, in the age group of 4 to 5 with an average of 58.6 months). Figure 4 illustrates participants' play in both conditions. The main purpose of the pre-pilot study was to uncover potential usability and experiment issues to inform improvements prior to the formal evaluation with autistic children.

Usability
There is sparse literature about AR systems designed for children younger than 6 years old. Therefore we examine the readiness of children aged 4 to 5 to interact with our AR system, which is essential to conduct experiments with autistic children of similar age. The study showed that children in this age group have no difficulty in interacting with the AR system involving simple manipulations with both hands (e.g. grab, translation, rotation) and in relating to another object (e.g. park the airplane in the hangar). This confirmed that their eye-hand coordination and fine motor abilities are appropriate to use the AR system. The participants sometimes need extra effort to align one AR object to a virtual object (e.g. move a car over a virtual bridge) maybe due to lack of physical reference and difficulty with depth perception in the mirrored view.

The frequency of pretend play is comparable in both conditions, although we expect a different outcome with autistic children due to their underdeveloped pretend play abilities. Participants enjoy the play more in the AR condition according to their self-report and parent observation.

Improvements
We identified several improvements during the usability study including the following. (1) We noticed that most visual indications provided by the AR system are rather simple comparing with other play ideas shown in the non-AR condition. This might cause pretend play to be

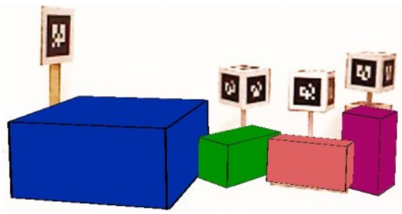


Figure 5: introduction of the AR system

less complex. To improve this, we added stronger situational cues in each scene (e.g. school bus/building, train station, rescue helicopter and fire). (2) One participant in the usability study was very interested in how virtual objects were shown on the display. Considering that autistic children are likely to be interested in computer technology, we added a demonstration before the tasks. The participant sees virtual objects of simple geometry shapes shown on trackable objects (Figure 5). They are then allowed to explore freely for up to five minutes to get familiar with the technology. (3) We chose to keep colours consistent for non-AR props of the same type to avoid colour matching play, and we replaced props with stimulus materials with similar ones made of plainer material (e.g. hair rollers covered by velcro to kitchen towel rolls) to reduce simple manipulation out of pure sensory curiosity.

Future Work

The usability study has confirmed that normally developed children above four years old are competent to interact with the AR system and produce various situationally appropriate pretend play activities. Our next work will be conducting a formal evaluation with autistic children within a similar age range to: (1) examine potential positive effects of the AR system in promoting pretend play (2) identify possible AR usability issues with less capable young children.

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