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Build our Town - Using an Augmented Reality Game to Enhance Young Children's Spatial Cognition

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Abstract: Having good spatial cognition strongly predicts children's later achievement in Science, Technology, Engineering, Arts and Math (STEAM) skills. How to improve children's spatial cognition properly and what type of games might enhance spatial ability were discussed in previous studies. Video games were proved significantly more effective than other games in improving spatial performance. Additionally, previous studies indicate that augmented reality (AR) technology present unique features to stimulate children's optimal spatial learning. This paper presents preliminary work illustrating the utilization of an AR game: "Build our Town" that combines a virtual world with a real board game for the purpose of enhancing young children's spatial cognition.

Keywords: Augmented reality, spatial cognition, young children, video game

1. Introduction:

Numerous studies demonstrate the reciprocal relationship between children's play and their learning (Yilmaz, 2016). Play is one of the most important part of a child's life. Children begin their learning as they explore their world through playing. Research on young children's use of play through video games have mixed results. Some research demonstrates that video games result in negative effects on young children's physical and mental development (e.g. Vandewater, Shim, and Caplovitz, 2004). In contrast, there is some evidence that video games may help children develop imagery, memory, language, logic reasoning, attention skills, problem-solving skills, and creativity if we use video games in an appropriate way (e.g. Dye, Green, and Bavelier, 2009; Staiano and Calvert, 2011).

"Spatial cognition is an important building block to general cognition, as it is the process that a child perceives, stores, recalls, creates, edits, and communicates about spatial images." (Osberg, 1997, p.1). During children's early years, their spatial cognition is developed through their interaction with environments such as, through play or parent's tutoring. The child with weak spatial ability is likely to have difficulty in his/her academic performance and may have challenges with daily adaptive skills (e.g., Jirout and Newcombe, 2015). Children can enhance their spatial ability by playing with constructional toys, or mazes and puzzle games, or even just by drawing a picture. In addition to the fundamental spatial skills, sensory processes, attentional processes, vision-motor coordination, speed, and memory are also considered as the indispensable cognitive processes that support spatial cognition. These cognitive processes are closely interrelated when players engage in a video game because the characteristics of video game such as the player's enthusiasm, focus, engagement, and persistence in their game tasks; quick interactive feedback to the player; appropriate difficulty in each level; risk-free setting makes the enhancement of these cognitive processes more feasible (Spence and Feng, 2010). With the technological evolution, augmented reality (AR) games such as "Pokémon go" swept over the whole world this year. The potential of AR technology for entertainment and presenting unique affordances for learning has attracted great interest (Bhadra, Brown, Ke, Liu, Shin, Wang, and Kobsa, 2016). According to Azuma (1997), AR technology can be defined as providing three features together: combining the real world with virtual worlds, providing interaction, and presenting three-dimensional objects. The combination of physical experience, virtual content, storytelling and the imagination of the child is the ideal learning experience for children (Stapleton, Hughes, and Moshell, 2002). However, there is a dearth of literature that focuses on young children and age appropriate toys developed with AR technology. From the current body of limited studies, some researchers have tested the effects of AR technology on spatial cognition skills, and children's attitudes towards AR (e.g., Bhadra, et al., 2016; Richard, et al., 2007). It is believed that AR technology could be widely used in enhancing children's spatial cognition development due to the fact that AR can provide tangible 3D objects along with 2D content, help children to practice mental rotation, 2D to 3D translation, mental slicing, and penetrative thinking. Children learn to recognize a map in a situated context. Additionally, AR can stimulate children's collaborative play and increase the frequent interaction between children with the game (Wu, Kai, Lee, Chang, and Liang, 2013). The advantages of AR technology make the development of an AR game for young children promising for improving children's spatial cognition.

2. Game Design

2.1 Explanation of the game

"Build our Town" is an AR technology based video game for young children to play. It explores a new technique application in the educational and entertaining environment, integrates the AR technology on a traditional board game in addition to offering an innovative interactive and situated experience. This game motivates children to use their imagination and spatial abilities to build a town by using the cardboards from a picture pool. Children practice their spatial problem solving abilities by learning to translate 2D pictures into 3D objects, and developing their overall arrangement ability while playing the game. Children move the cardboard and match different cardboard pieces together in reality upon an AR tile, and the AR space (mirror image of children and their cardboards upon the tile) showed in the mobile device will transfer a 2D object from cardboard to a 3D object supported by AR technology. In AR space, the river can flow, the car can move, and the people living in the town have their own "life".

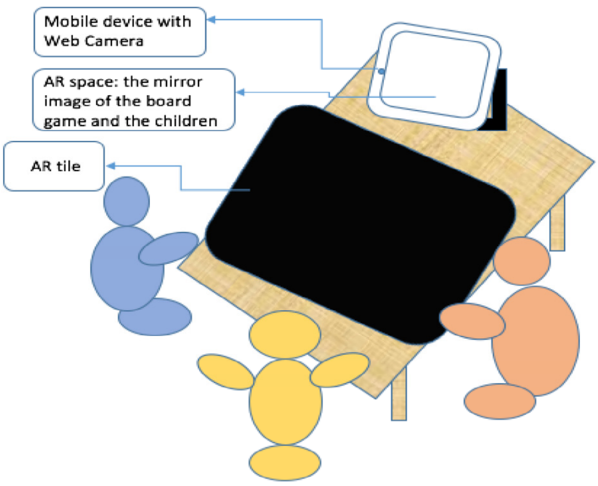
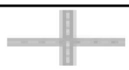


Figure1. Children Playing the Game While Seeing the 3D Mirror AR Image in the Mobile Device

There are 5 kinds of cardboards in the picture pool: 1) location cardboard (home, hospital, school, etc.); Every location has four views: front view, back view, side view and top view; 2) road cardboard (one-way street, crossing, etc.); 3) avatar cardboard (mother, father, etc.); 4) nature cardboard (trees and flowers, etc.); and 5) special cardboard (river, bridge, car, fountain etc.). When children pick up one cardboard and put it on the AR tile, the mobile device of AR space will show its corresponding 3D style image. Children pick up one location cardboard at a time and use road cardboards to connect each location, different road cardboards may have different road types, such as a crossing road, T-junction, etc.

Table 1: Examples of the comparison of cardboards (2D) and corresponding AR images (3D)

Number	2D cardboard (front, side, back, top view)	3D in AR space	Detail
1			Church
2			Cafe
3			Shopping mall
4			School
5			Truck
6			Gas Station
7			Crossing road
8			Fountain

2.2 Two or more ways to play and explore

An initial way to play the game is called the matching module. Augmented reality space in the mobile device presents a finished 3D town. Children follow the layout of 3D town to have the town "reappear" using 2D cardboard on AR tile. The children match every different kind of road cardboard with each other while they also attend to their locations. Not every location card can match with every road card. In the 3D town, the building might have a different orientation. Children are required to distinguish various building's location and orientation, and put their 2D cardboard in the matching orientation. Only when every location cardboard and road cardboard matches the right place, children will win. The purpose of this module is for children to practice their ability at recognizing 3D objects with its associated 2D counterpart. Children can choose different levels of difficulty for the game to make it more or less challenging.

Children also can design their own town while engaged in pretend play (such as role play as a mother, or a doctor). They pick an avatar from the cardboard. The cardboard avatar also has its corresponding 3D figure in the virtual town. The children can also choose their preferred and imaginary lifestyle. For example, if they want to go to the park, they need to figure out where the park is located. If they did not "build" a park yet, they will need to choose the park cardboard and then find a matched road to connect the park to their home. Children can also add river cardboards in their game, and they can build a bridge over the river. Children can build a town on their own or collaborate with partners. Children can discuss with a partner to decide their total layout and make sure that every road can go through the town. Collaborative work is encouraged because this can help children increase interaction with each other thus enhancing children's social ability while also promoting children's cognitive skills. After the children finish their design, they can put one "car" cardboard in the street, and the car will "drive" in the AR space. A "timeline" can be added into this game to make the life in the game more interesting. If children click the button in the mobile device "add a clock", the clock will show in the interface, and if children add a "bell tower" into their virtual world, the bell tower will strike every hour. All transports in the road can make noises, and children can follow the instruction to add the traffic lights and the traffic signs. Children can use their finger to move the screen of the mobile device. The virtual town in AR space can be viewed as a panorama.

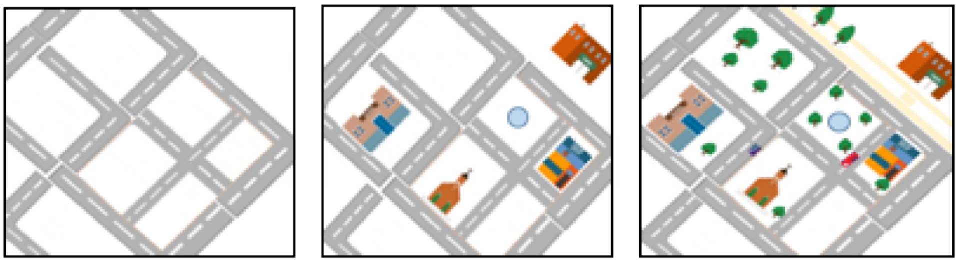


Figure 3. The Process of Building the Town with Cardboards (2D objects)

Figure 4. The Process of Building the Virtual Town in AR Space (3D objects)

2.3. Related game and this game's contribution

The conception of this game was inspired by a cardboard game called "community" produced by eeBoo. "Community" makes children connect home and location tiles as efficiency as possible using a set of road tiles. With the rise of AR technology, there is still a limited number of appropriate AR games for children to play. In "Build Our Town", children can obtain and improve the following skills: imaginary, 2D to 3D transitions, spatial orientation, collaboration, mental rotation, attention, memory, organization, planning and problem solving, multi-sensory processing (visual, auditory and motor), social and collaborative interactions when played with partners, self-control and self-confidence. The purpose of this game is to stimulate children using their creativity to build a virtual town. Children will enjoy this game, and pretend they are living in this town, which might help children to learn the 2D-3D transitions through play. The game will attract children's interests during their interaction with AR space, and children will learn abundant spatial knowledge with fun. This game is a new educational game using AR technology, and will fill the gap in the educational game based learning field.

3. Future work

This paper describes a conception of an AR based educational game to enhance the spatial cognition of young children. The next steps of the current study would be the implementation of the game and the techniques needed to make the game become applicable. Children's knowledge construction process, cognitive attainments while playing the game should be investigated in a further study (e.g., Yilmaz, 2016). Augmented reality technology will provide children plentiful interactional opportunities between the game and with each other when playing the game with a peer. How to keep children interested in the game, what kind of behavioral actions children exhibit during their playing, and how to implement the useful and proper instructional strategy by teachers and parents are also important elements to study in the future. The issues of children's selection preference; the game's accompanying sound audio; and the game's data mining also will be explored in the future.

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