Conference Paper

To Develop and Evaluate Children's Cognitive Development through An AR-Playful-Learning Approach

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Abstract

Augmented Reality (AR) technology have been recognised as an effective experience enhancer with a broad application range. It is challenging to explore such potentials in the area of learning and teaching by utilising AR features in behavioural stimulation and monitoring. In this study, the author aims at exploit AR technology to institute a system for cognitive development. The principle goal of such playful learning system is to improve the overall ability of toddlers to function in social environments through cognition forming and behavioural redirecting. This paper introduces an interactive training game that assists children between two and seven years old to develop their cognitive model through intuitive theory-based educational AR gamification. A pilot study implements Montessori training theory is described in this paper.

Keywords: Augmented reality, cognitive model, pre-operational development, playful learning, behaviour analytic process, Montessori training theory

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1 Introduction

Cognition development is one of the most important steps in children's life [1]. Without a proper established cognitive model, they will have trouble functions in later life. In the worst scenario, people with deficit cognition might lead to mental disorder [2]. Many products in the current market have displayed the ability of cognitive training for young children. However, most of these products in the market have drawbacks with either lacking of theoretical evidence or be deficient in expressing playful learning interactions. This paper presents a new method of developing and evaluate children's cognition through Augmented Reality (AR) playful learning games.

In the past decade, designers have realised the importance of utilising human psychology - a perpetual processing loop of feeling, understanding, and acting for design purpose [6]. In most cases, human's mental model can be gained through experience and then processed literately through human's entire life, to construct human's cognition gradually. The mental model is equivalent to human's overall perception, which represents user's attitude towards the world [7]. In other words, human act differently

because they have various mental models. From the perspective of the information provider, understand the receiver's mental model could be vital for successfulness of the information exchange [8]. Moreover, mental model could construct human's cognitive model, which stands for the action process from sense to action.

Why AR? Well, according to psychologists, when human receiving information from outside world, the data processing procedure could be divided into three different level: Visceral, behavioural, and reflective [5]. Augmented Reality (AR) is a display technology that has embraced its flourish in supporting behavioural cognitive related visual experiences. Compare to VR, AR is more capable with facilitating connections between users [4]. Since AR implements see-through devices that allow users to observe the physical environment along with virtual add-on, AR is more interactive than VR. In other words, AR is the most appropriate technology to provide an interactive experience to the user.

AR provides more extended visualisation by overlaying computer-generated virtual 3D contents on top of reality than other display technologies. Most of the cases, exhibiting AR elements requires a see-through digital camera of a mobile device or an eyewear with digital high-definition lenses. When operating AR technology, the user needs to grip on the mobile device or put on the eyewear, then face the devices at a specially designed trackable marker [3].

2 Methods

Human has likely been playing games for a long time, probably longer than the history of speaking or even standing on two legs. Literature review shows that the majority of people, especially children and toddlers, are more likely to engage with the world through playing [10]. Playing is the uppermost aspect of their mental model [12]. Piaget's study also revealed that when children and toddlers are processing information, mainly in the learning process, their cognitive model will be better developed if multiple playing actions have been involved in the procedure [13].

2.1 Playful learning

Playful learning is a concept to encourage user to gain knowledge through entertaining study process, which has become as one of the most promising approach for the educational industry with a broad application range. Especially, it is challenging to explore such potentials in the area of learning and teaching by utilising AR features in behavioural stimulation and monitoring. As being a method could potentially be more efficient in enhance interactive Human Computer Interaction (HCI) compare with traditional teaching process with props, AR technology could improve learning experience

Category	Sample product	Interactivity	Entertaining	Experience	Information exchange	Knowledge providing	Cognition development
Plain flash card game	Flash card	3	1	2	2	3	1
Plain book reading	General teaching	1	1	1	1	5	3
Digital adventure game	Camp discovery	2	3	3	1	2	2
VR experience adventure game	Medical VR	5	2	5	1	2	4
AR card training	Osmo	5	4	4	2	3	5

Figure 1: MARKET SURVEY.

by complementing static objects, producing supplementary information to students. In other words, AR has the possibility to let user learn by experiencing instead of reading.

From previous research, the author found that, firstly, human form their cognition model from experience, which could be offered by AR environment. Secondly, children between age two and seven construct their cognition through games. The author made a presumption that enriched AR playful learning game could provide better development for children's cognitive model. With the intention to prove the hypothesis above, the author carried out a user survey, which focusing on the effectiveness of different learning techniques (Figure 1.).

The author made a Likert scale to rate for different aspects of sample products. Accessing aspects include the interactivity, entertaining, experience providing, information exchanging and knowledge offering according to previous research. User survey made clear that playful learning is more beneficial for children compare with traditional learning methods regarding cognitive development.

2.2 Behaviour monitoring

Cognitive model reflects human's mental movement from receiving information from outside world to giving equivalent reactions [14]. The author has conducted several user tests in past studies, despite the objects shares similar age and background, their responses towards certain products are various. The literature review has revealed the science behind this situation. Even though a group of human are sharing the similar background, as their cognitive constructing approach could be influenced by varying contexts, their cognitive models differ from each other, which result in various reactions [15].

Human's reacting behaviour could demonstrate their cognitive model to a certain extent. Put in other words, human's cognitive development condition could be assessed by behavioural monitoring.

2.3 Montessori training theory

Montessori training theory is an educational approach, which has been proved to be effective in cognition development for children. It facilities a rich experienced learning

environment and provides opportunities for children to act base on different tasks. The goal of Montessori theory is to enable children to be independence and initiative by emphasising the independence, respect, and limited freedom for children's natural context [16].

From previous research, playful learning could enhance children's cognition development by providing learning objects through attractive games [10]. As Montessori training theory has already proved by researchers that it could be beneficial for cognition forming, the author intent to design the contents of the playful learning game base on Montessori theory. The game is deducted to have positive effects since the approach and contents are all been validated by research.

2.4 Social acceptance

At the era of technology and entertainment, many concerns have been raising regarding young children engaging with digital games. Parents and caregivers are anxious that digital games could potentially harm young children's visual functions, and the expose to games could isolate the children from others [17]. However, researchers have found that parents and caregiver are more acceptable to game playing when the digital game is aims for educational purposes, especially when the children are experiencing late development of cognitive model [18].

3 Design Rationale

The potential of utilising AR technology to enhance cognition development has been emphasised through this study. The author proposes a new method to develop and evaluate children's cognition condition through enriched AR playful learning experience. The principle goal of such approach is to improve the overall ability of toddlers to function in social environment through cognition forming and behavioural redirecting. Since toddlers and young children are insufficient in processing objects and events, AR featured educational game will be more effective by yielding an efficient and appealing playful learning system for children between age two and seven, though others could also benefit from it.

The author designed an AR playful learning game with Montessori contents base on research results. As above mentioned, Augmented Reality technology has been proved as an experience enhancer with the advantage of intuitive and interactive, which could provide a rich experience to its user. Moreover, experiences could form human mental model and gradually construct the cognitive model. Thus, the game is made in AR environment with various daily experiences. Furthermore, from Jean Piaget's cognitive development theory, the most effective period for human to development cognition happens at what Piaget called the pre-operational stage, which starts from two

to seven years of life, where toddlers and young children will progressively develop cognition through playing. Research has found that not only playful learning could encourage children to form their cognitive model, Montessori training theory could also educate children's cognition. Therefore, the author determined to utilise Montessori theory to create the game contents. Additionally, due to the operation process of human's mental model [15], which is the attitude and baseline for constructing cognition. Human's cognition condition could be evaluated by monitoring their behaviour, which could be easily detected by body sensor. Accordingly, a behaviour detecting system has been added to the game to evaluate user's cognition condition and the progress.

3.1 Software – game contents

This game is carried out by exhibiting various customisable game contents which are essential for toddler's cognitive development base on scientifically proved cognitive development theory, Montessori training theory. The virtual 3D game contents such as daily objects and social sensory are generated from AR trackable flash cards to provide an intuitive experience in the real world. Children could create their own storyline and game scenario by adding and changing flash cards. The characters in this game are featured with easy recognising shape attractive animation, which intent to teach the player daily objects and social skills to gradually form user's cognitive model. There are five game modes (figure 2.).

1. Character defining: User could customise the characters in the game by defining the appearance and trait, it will create the bonding between virtual character and the player.

2. Context experiencing: AR technology provides a rich experience of daily scenarios, to let the players feel the context as they are there.

3. Object learning: Montessori training theory has been applied in this mode. Object learning session provides knowledge of everyday objects, which aims to educate the player's cognition.

4. Emotion expressing: Human's emotional expression could reflect their attitude towards the world, and vice visa. To teach the players to express their feel is vital for forming their mental model.

5. Use as a tool to interact with other people: A simple capture mini game in the playful learning system will let the player interact with real people in the real world. The benefit of such mini game is multilayered, firstly, it offers a rewarding and entertaining method for players to relax from skill learning. Secondly, it creates a tool for young children to communicate with others through play, especially for introverts. Thirdly, it is a way to solidify the knowledge the player has learned from training game as the objects in this mini game are all previously learned.

Figure 2: FIVE GAME MODES.

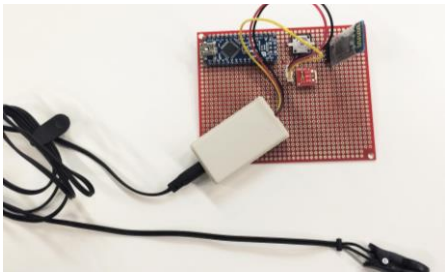

Figure 3: DETECT SENSORS.

3.2 Hardware – behaviour monitor

Not only capable of playful learning, the system also able to record and analyse player's concentration and responsiveness condition through two collected data stream. One is player's behavioural data, which is gathered from body gesture detecting sensor (figure 3.). Another data stream comes from player's performance in the game, such as the duration of each presented flash cards and the quickness of making decisions. Collected various data inputs will be processed by a series of analysis outcomes with a system embedded algorithm, to displayed on a user-friendly interface for the caregiver to check progress.

4 Discussion

Piaget [9] defined four cognitive development stages of human, which lasts from birth to 16 years old [10]. The first stage extends from birth to approximately two years of life, called Sensorimotor stage. In this stage, infants gain experiences from hearing, vision, and the interaction with objects. Coordinate with such experiences, and they will progressively construct knowledge and understanding of the world. Understanding that objects continue to exist in the world even though the infant cannot experience it is the milestone of this stage.

The second stage is Pre-operational stage, which starts when the toddler begins to speak to roughly seven years old. From two to four years of age, toddlers attempt to understand the concrete logic by symbolic play such as imaging a box being a table. At between the ages of four to seven, children tend to perceive knowledge by curiously asking. Toddlers and children will gradually form the cognition to manipulate information mentally [11].

The last two stages of cognitive development are Concrete operational stage and Formal operational stage, which happens in pre-adolescence and adolescence. In this two stages, children and young adult will continuously comprehend the skill which appropriately uses logical thinking to understand abstract concepts by hypothetico-deductive reasoning.

As above mentioned, human's cognitive model could be interpreted as the procedure from sensing, processing to taking action towards information. Processing information requires logical thinking. Without a doubt, from Jean Piaget's study, the most critical stage of forming logical thinking is the pre-operational stage. In other words, children between age two to seven will construct their cognitive model more efficiently than other age groups through play.

5 Future Work

In the current phase, there are two parts in this playful learning game have been achieved.

1. The gaming system;
2. The monitoring system.

The gaming system provides Montessori based game contents that will progressively construct player's cognition. The monitoring system observes player's performance from both system and behaviour detector. The player will react to game contents, and then the performance will be assessed by system algorithm. In the meantime, the game contents will be automatically altered base on player's cognition analysis.

Several user testing has been conducted to evaluate the usability of the proposing system, yet due to the natural of human's cognition development process, it requires a long time to assess the practicability of improving cognition in this method.

Future work will include practicability testing and system modifying base on player's feedbacks.

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