A Usability Study on Table-Top Augmented Reality Games for Elementary School Students

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Abstract: The aim of this study is to evaluate the usability of three table-top augmented reality games, including Punch the Rats, Learning Vocabulary and Animal Classifications. The ten subjects of this research are all sixth grade students of an elementary school in New Taipei City. In order to evaluate the usability, the researcher uses the three usability dimensions of ISO9241: "Effectiveness", "Efficiency" and "Satisfaction". The results of this study indicated that games with appropriate feed-back design are more likely to be quickly familiarized, and the girls need twice as much time as the boys do to understand how to play the game. Users found the new style of interaction very interesting, and would like it to be applied to the learning of English vocabulary, math, and nature science.

Keywords: augmented reality, usability, table-top games

Introduction

Augmented Reality (AR) brings the virtual objects into the real world where we live. It not only provides a natural way to explore 3D objects but also makes the interaction between human and computer more instinctive. With increasing development in augmented reality, it has been applied to digital games[5], education[4] and, medical rehabilitation [1].

Combining the see-through head-mounted display (HMD) and the pre-defined markers on a physical cubes, magic cube [7] provides a new experience to the field of interactive storytelling. Tangible cubes[4] is also uses HMD, markers and cameras to develop an educational game for children to learning the endangered animals. The results indicate that children enjoyed playing the AR game. Even though the children felt the real game is harder than the AR game; however, they preferred the AR game to the real one. Without using the HMD, table-top AR game can be realized more simply with a camera (or a webcam) and the pre-defined marker. GenVirtual [2] and ARVe (Augmented Reality applied to Vegetal field)[6] are designed based on this structure. Both of the AR games are used to help the cognitive disabled children.

Although lots of AR games have been applied to elementary education; nevertheless, there is little research on the usability of table-top AR games. The aim of study is to evaluate the usability of the table-top VR game, and to know the limitation and difficulty when children are operating it.

1. Method

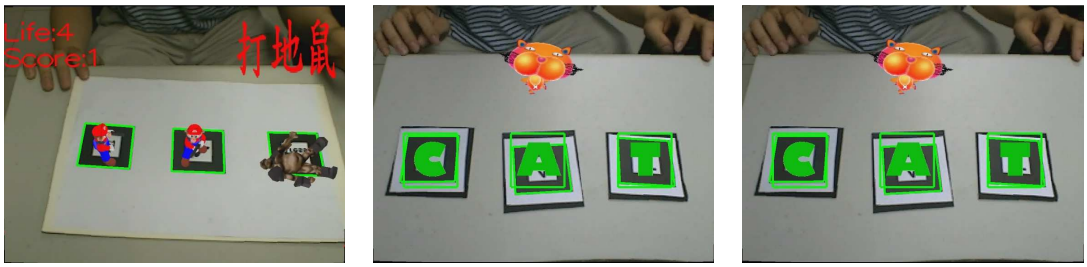
1.1 Participants

The participants in this study were ten sixth grade students (five boys and five girls) in an elementary school in New Taipei County. All of the students had played computer games with an average of 1 to 4 hours a week, and had no experience with this type of table-top AR games.

1.2 Experimental Design

In this study, three table-top AR games (see Fig. 1) are designed with a low cost webcam and the pre-defined makers on the tangible pieces. The virtual objects are display on top of the markers on the screen in real-time and the interaction is based on the physical and direct interaction with pieces on the table. Once the Mario is hit, the player will lose one life. The goal of this game is to score as high as possible.

- Punch the Rats: The game will be started when the three markers are pressed simultaneously and five lives are given for each game. Mario or monster will be rendered randomly on top of each marker. The player gets one point each time he hit a monster.
- Learning Vocabulary: Three squares are on top of the board. If the player could place the predefined words with their letters in correct order, the corresponding virtual character will be displayed on the screen. For example, in Fig.1(b), a cartoon cat is displayed when three letters 'C' 'A' 'T' are placed in the squares with the correct order. That is, the objective of this game is to arrange the letters in the proper order to form the word. The game is still under development, only four simple words, including CAT, ACT, DOG and GOD, are implemented in this game.
- Animal Classifications: In this game, two different regions, ocean and grassland, are provided and can be switched by pressing the square with the word "Press"(See Fig. 1(c)). The square with the word "場" is used in positioning the board only. Player can place elephant or whale in the selected region by moving the predefined makers in front of the camera. The purpose of the game is to teach students how to identify animals and their habitats. That is, the elephant should be placed in the grassland and whale is in the ocean.



(a) Punch the Rats (b) Learning Vocabulary (c) Animal Classifications

Fig. 1: The three table-top AR games.

1.3 Procedure

The usability study included two phases. First, the participants were asked to play the three table-top AR games individually and these games could be played in any order in which the participants wished to play them. The only assigned task for the participants was to understand the goal of these AR games without any further instructions. Besides, the

participants were asked to verbalize their thoughts while performing the given tasks. The task is considered completed when the participants could know how to play and correctly verbalize the goal of the playing game. In order to obtain more objective results, all participants had no opportunity to discuss theses games with each other and the entire process of the experiment was recorded by video recorder. Second, the participants filled out the questionnaire individually after finishing the given task, and then a semi-structured interview was conducted to understand more about the preferences and satisfaction.

1.4 Data Analysis

The efficiency was measured from the task completion time, which is the time between the beginning of the task (the participants start the playing) and the end (the participants can correctly verbalize the goal of the playing game). Since the participants had successfully completed all assigned tasks, the effectiveness was measured in terms of difficulties encountered by the participants in playing the games instead of the error rates. The satisfaction was obtained from the questionnaire results and the semi-structured interview.

2. Results

2.1 Efficiency and Effectivness

Table 1 summarizes the average task completion time for each individual game. The results indicate that the participants spent less time in understanding the gameplay of Learning Vocabulary and Punch the Rats compared to that of Animal Classifications. For Learning Vocabulary, these three squares offer a simple and intuitive cue, which makes participants able to place alphabets in these three squares. Although, Learning Vocabulary had the fastest average task completion time (M=72.80), but the participants feel unaccustomed to play with the reversed alphabets on the screen.

Punch the Rats is the most informative game. It provides clear and obvious instructions for the players; for example, the game will start when the three markers are pressed simultaneously; hence, the participants could use less time to understand the gameplay (M=89.30). However, the participants complain that their scores are affected by the displacement of the board when they tabbing the monster.

Animal Classifications takes the participants more time to understand the gamplay(M=208.30), because it does not provide clear indications to guide the users. Besides, the “Press” button sometimes does not work. This error makes participants feel confused and frustrated in playing this game, especially for the participants who choose the Animal Classifications as the first game.

Table 1 also shows the average task completion time for the game with the playing order. It is obvious that participants take more time to understand the gameplay of the first game, because they are all the first-time players of AR games. After having the experience with the AR game, the participants, on average, can save about 50 seconds to familiar with the gameplay of the subsequence games.

Table 1: Average task completion time for each game

	Average task completion time(seconds)	standard deviation
Punch the Rats	89.30	99.786
Learning Vocabulary	72.80	49.213
Animal Classifications	208.30	102.207
The first game	158.60	118.805
The second game	106.40	115.343
The third game	105.40	74.126

Table 2 shows the average task completion time for boys and girls on playing these games. The results indicate that gender will have an influence on the average task completion time. For Punch the Rats and Learning Vocabulary, boys (M=41.78,52.72) spend less time than girls(M=128.61,90.11) in understanding the gameplay. This may be relative to the boys' existing gaming experience; therefore they can acquaint themselves easily with this new type of games. Hence, boys would try different ways than girls to find the solutions when encountering bottlenecks during the game.

For Animal Classifications, there is no obvious difference between boys'(M=209.67) and girls'(M=209.44) performance. Lack of meaningful instruction and poor designed feedback are the causes of this phenomenon, because players will spend a lot of time to explore the game.

Table 2: Average task completion time for each game

AR Games	**Gender**	**Average task completion time(seconds)**
Punch the Rats	Boy	45.00
	Girl	133.60
Learning Vocabulary	Boy	55.20
	Girl	90.40
Animal Classifications	Boy	208.20
	Girl	208.40

2.2 Satisfaction

Two groups of five participants chose Punch the Rats and Learning Vocabulary as their favorite games respectively. Being funny, easy to play and able to learn English simultaneously is the reason why they chose them. However, no one likes Animal Classifications. It shows that meaningful instruction and well designed feedback play an important role to attract the attention of players. Seven participants regard Learning Vocabulary as the easiest game to play owing to the intuitive user interface that participants can easily perceive and understand. That is, a table-top VR game with an intuitive user interface is more likely to be accepted by the players.

Eight participants stated that the way to play this kind of table-top AR games is not difficult and they liked it. However, two participants disagree with it because poor designed feedback, lack of meaningful instruction and error recognition make them feel frustrated. Most participants believe that this kind of games is interesting, easy to play and convenient but need accurate recognition and meaningful instructions.

In addition, participants hope that the table-top AR games could be applied to more learning activities. Seven participants advise that the designed AR games provide not only learning vocabulary but also learning the sentence structure. Two participants suggest that could the AR games be applied to mathematical learning because it's difficult to learn mathematics for most students. Their motivation of learning mathematics may be increased with the AR-based learning activities. One participant hopes the table-top AR game can take the classification of plants into consideration.

3. Conclusions

In this study, three table-top AR games had been implemented and three usability dimensions of ISO9241 (effectiveness, efficiency and satisfaction) were applied to evaluate the usability of these games. Although, these three games are still under development, the participants found the new style of interaction very interesting and gave us positive feedback and valuable suggestions about these games. Learning Vocabulary is regard as the easiest game to play due to the intuitive user interface. Punch the Rats provides rich and meaningful information for players. Both of the games are regarded as favorite games by the participants. This shows that rich and meaningful instruction, well designed feedback and intuitive user interface play an important role to attract the attention of players.

As suggested by the participants, the table-top AR games could be applied to the learning of English vocabulary, mathematics, and nature science. As AR technology hardware and software improve, we believe that these applications can be realized with the table-top AR technology in the future.

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