Learning words using Augmented Reality

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***Abstract*—** This paper presents an Augmented Reality (AR) game for learning words. Thirty-two children played the AR game and the equivalent real game. We have compared the results of the two games. The results indicate that children did not found significant differences between the two games except for one question, but 81% of the children liked most the AR game.

Keywords: Augmented Reality, learning words, edutainment

I. INTRODUCTION

Learning letters and words is one of the first tasks that every child has to do, it does not matter the language. There are many commercial toys related to this topic, but any of them uses Augmented Reality (AR). AR is a powerful technology that can be applied to this task. This paper presents an AR game for learning words. To our knowledge, this is the first system that uses AR for learning words, but it is not the first one for learning other subjects. For example, The Virtual Showcase [1] placed virtual objects on real artefacts. One of the most outstanding applications was to place skin and bones on the skull of a Raptor dinosaur. Shelton & Hedley developed an AR system for learning the relation between the earth and the sun [2]. It included rotations, revolutions, solstices and equinoxes, and seasonal variations of light and temperature in the hemispheres. Construct3D [3] was designed for learning mathematics and geometry. With ARVolcano, the children can learn about volcanoes, which included details on subduction, rifts, the Ring of Fire, volcano formation, eruptions and tectonic plates [4]. It is also possible to learn organic chemistry using AR [5] or anatomy [6]. With PlantStory is possible to learn how the plants germinate, disperse, reproduce and perform photosynthesis [7].

This paper is organized as follow. Section 2 presents the AR game and includes the software and hardware requirements as well as a description of the game. Section 3 presents the results of the game. Finally, in section 4, we present our conclusions, our suggestions for improvements and future work.

II. SYSTEM DESCRIPTION

As AR game, our game requires accurate position and orientation tracking in order to register the virtual elements in the real world. We have used a marker-based method. Therefore, our game requires a camera to capture the real world. The game processes the captured image and recognises the visible markers. A marker is a white square with a black border inside that contains symbols or letter/s. To capture the video, we have used a USB camera (QuickCam Pro for Notebooks). This camera has the following features: captured image size - 1600 x1200 at 30 fps; focal length - 3.7 mm.; automatic focus adjustment and RightLight 2 technology with the capability to adjust the webcam to take good shots even in dim light settings. The output of the game was shown on a 5DT Head-Mounted Display (HMD) (5DT Inc., 800 Hx600 V, High 40º FOV) and on a screen. In this way, the child wore the HMD and the person in charge of the tests could see the same scene as the child saw on the HMD. The camera was firmly attached to the HMD on its front part.

To develop the game, we used the OsgART library (www.artoolworks.com/community/osgart). OsgART is a C++ library that allows developers to build AR applications using the rendering capabilities of Open Scene Graph and the tracking and registration algorithms of ARToolKit [8]. A virtual pet (a robot) was developed using Switf 3D (Figure 1). Cubase SX was used for the modification of the recorded voice in order to be similar to a robot voice. The audio was saved as MP3 files. Adobe Premier was used for mixing the virtual pet with his audio.

In our AR game, fourteen different markers are used (Figure 2). Each marker has its own functionality. However, they can be divided into three groups. First, the markers that are only used for showing images over them (10 markers, the markers shown in the two first rows of Figure 2, starting from the top of the image). These ten markers can be subdivided into two subgroups. These subgroups associate a different functionality to the same marker. In the first subgroup, six markers are used for showing the main menu. In this main menu, the children can choose the game to play.

This menu contains: 1) Spell the word. 2) Start with ... 3) End with ... 4) Complete the word 5) Look for the intruder 6) Finish. In the second subgroup, the ten markers are used for showing the images of the letters for forming words. The letters can appear in upper case letters (e.g. Figure 3) or lower case (Figure 6) letters. Second, the markers used for navigating into the content of the system (third row of Figure 2, starting from the top of the image). Any virtual element appears over these markers. The SI(yes)/NO(no) markers are used for answering to questions asked by the virtual pet. The player uses the marker with the tick symbol for asking the game to check if the word is right or not. Third, a marker in which over videos of the virtual pet are shown (fourth row of Figure 2, starting from the top of the image). The videos are: explanation of the different games, encouraging sentences when the child correctly answered or advising sentences when the child wrongly answered.

With regard to the game for spelling words, the children have to spell the word asked by the virtual pet. The words have a maximum lenght of ten letters (the number of markers used). Over several markers (the number of letters of the word) appear letters. Over the rest of the markers (ten minus the number of letters of the word) appear coloured squares, indicating that these markers are not used to spell the word. The child has to place and align the letters in order to complete the word. On top of the markers with letters also appear images that help the children to recognise the letter. These images are normally used in Spanish classes to recognise letters. Figures 3 and 4 show an example of this game.

With regard to the start with game, the children have to complete the word asked by the virtual pet with the initial letter. The person in charge of the game places the markers for the word in the lower area and three markers with three different letters in the upper area (Figure 5). The child has to choose the right letter.

The end with game works as similar as the start with game does. But in this case, the child has to complete the final letter of the word asked by the virtual pet.

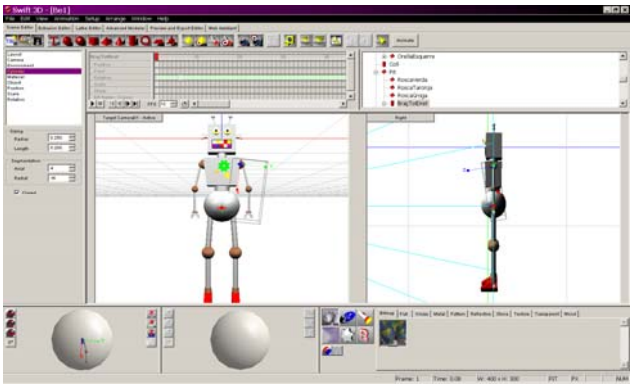

Figure 1. Virtual pet developed using Swift 3D

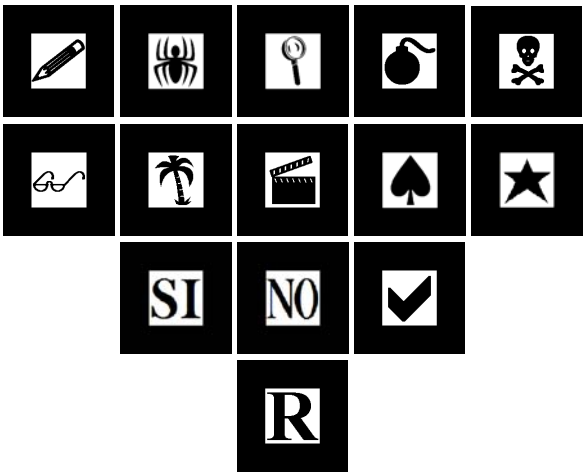

Figure 2. Markers used in the games

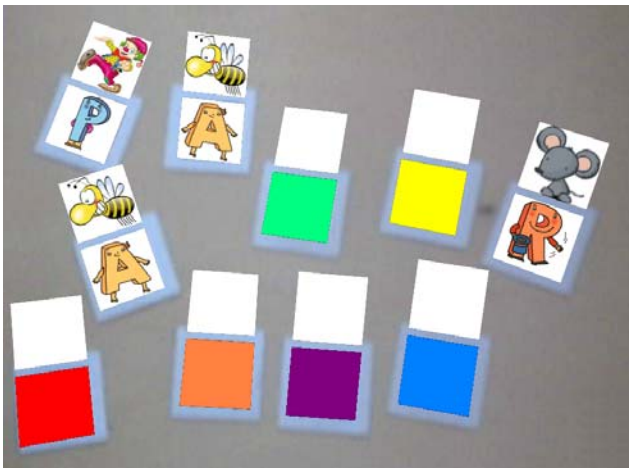

Figure 3. Spell the word game. Initial position of letters for spelling 'ARPA'

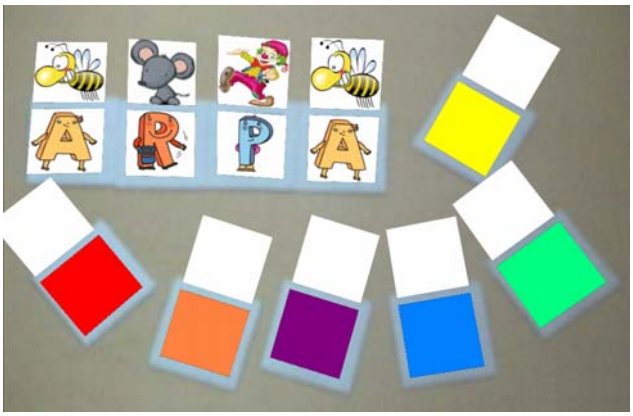

Figure 4. Spell the word game. Final position of letters

Figure 5. Start with game. Initial position of letters for completing the word 'TROMPETA'

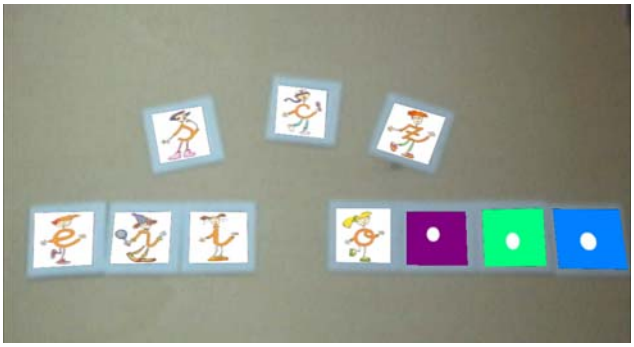

Figure 6. Completing the word game. Initial position of letters for completing the word 'erizo'

The complete the word game is a different version of the two previous games where the child has to find the missing letter. This missing letter can be anyone different from the first or the last letters. As in previous games, three possible letters are offered and the child has to choose the right one. The person in charge of the game has to place correctly the markers. The child only has to choose one of the three letters and places it in the empty space. Figure 6 shows the initial position of letter for completing the word 'erizo'.

With regard to the look for the intruder game, the children have to look for the letter that does not belong to the word pronounced by the virtual pet. The game works as similar as previous ones.

To sum up, the order for using the game is the following: First, the person in charge of the use of the game places the markers for the main menu. For choosing one of the options, the child places the marker with the tick symbol over it. Second, the person in charge of the use of the game places the markers for the selected game. The child has to place the right marker (the one with the right letter) in the right place depending on the game. Later, the player uses the marker with the tick symbol for asking the game to check if the word is right or not. Figure 7 shows a flowchart that represents how the game works.

In order to be able to extend the game to other games/words/languages with minimum changes, we included as much information as possible in XML external files. They are four groups. The first one, configuration.xml, contains the identification words for the five games. In the second group, there are five files containing the words to be used in each game. One of these file stores the common information for each game. This common information includes the common paths of virtual pet videos. The rest of the files store for each word identificator, the number of letters, the image associated to the ten possible letters, the word to be used, the video path for asking it, and the videos path for finding or not the right letter. The third group has four files, games.xml, lettersupper.xml, letterslower.xml, help.xml. These files contain the paths of: letter images, help objects, and the images for the different options of the main menu. The last group of files contains one file, highscore.xml. This file is used to store the children's scores.

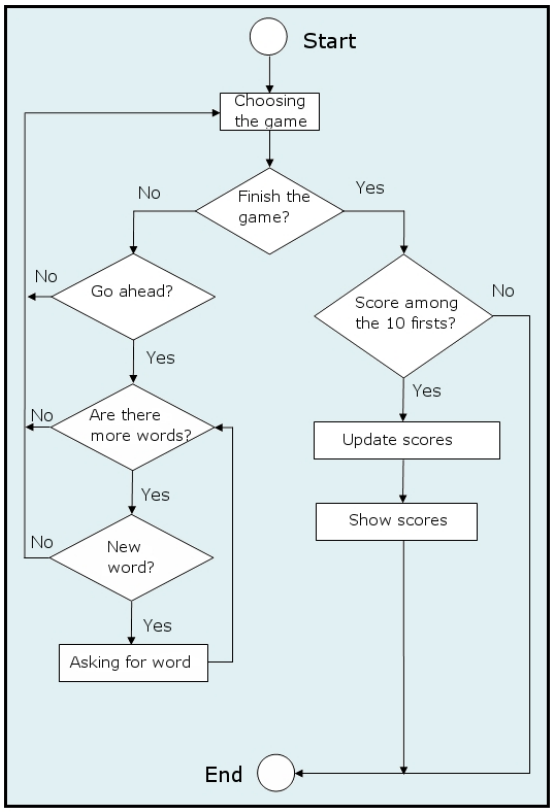

Figure 7. Flowchart represeting how the game works

III. STUDY AND RESULTS

The study included 32 children, 14 boys and 18 girls. They were primary school students (aged from 5 to 6 years old, mean=5.9, SD=0.3). Children were counterbalanced and assigned to one of two conditions:

a) Children who used the real game first and then the AR game.
b) Children who used the AR game first and then the real game.

The protocol was the following. Before using either game the children were told how to play the games. The

children then played the first game. The children played the five games in the AR and the real versions. The order were the following: 1) start with, 2) end with, 3) complete the word, 4) look for the intruder, 5) spell the word. The children worked with three words in both games.

After the game, the children were asked to fill out a post-game questionnaire. After filling out the questionnaire, the children played the second game. After playing, the children were again asked to fill out the post-game questionnaire. Finally, they were asked to fill out a final questionnaire. The children played with the AR game at about 15 minutes and with the real game at about 10 minutes. All the questionnaires had to be answered on a scale from 1 (not at all) to 7 (very much). The AR post-game questionnaire contained the following questions and statements:

AG1. I enjoyed playing this game
AG2. The game has been fun
AG3. Has it been easy to play?
AG4. It has been easy to choose the type of game I wanted to play.
AG5. It has been interesting to play a computer game by moving real markers.
AG6. I have had the sensation to be playing with cards over them appeared words and images.
AG7. I think playing this game I can learn to spell words, complete them and looking for the intruder.
AG8. I would like to play again
AG9. I think that my friends and relatives would like to play this game
AG10. How much have you learned?

The final questionnaire contained the following questions and statements:

F1. Which game did you like the most?
F2. Why?
F3. Add any comment about the experience.

TABLE I. MEANS (SD) OF THE TWO GAMES, AND PAIRED T-TEST FOR SCORES GIVEN TO THE POST-GAME QUESTIONNAIRE

Quest	AG1	AG2	AG3	AG4	AG5
AR	6.78 (0.66)	6.53 (1.02)	6.00 (1.63)	6.59 (0.91)	6.47 (1.16)
Real	6.72 (0.68)	6.72 (0.52)	5.97 (1.79)	6.38 (1.07)	6.44 (1.01)
t(31)	0.70	-1.06	0.13	0.93	0.12
p	0.488	0.296	0.897	0.362	0.905

Quest	AG6	AG7	AG8	AG9	AG10
AR	3.59 (2.18)	6.75 (0.62)	6.81 (0.47)	6.50 (0.98)	6.72 (0.52)
Real	4.84 (2.36)	6.47 (1.05)	6.78 (0.49)	6.66 (0.70)	6.78 (0.49)
t(31)	-2.32***	1.79	0.27	-1.0	-0.49
p	0.027***	0.083	0.786	0.325	0.625

**' indicates significant differences

The significance level was set to 0.05 in all tests. Table I shows paired t-tests for the scores given to the post-game questionnaire after playing both games. As this table shows, there was no statistical difference for all questions except for AG6. This indicates that the sense of presence was not the same with the two games. We would like to highlight that mean scores for each question except for AG6 were high (>=5.97), with a mean of means of about 6.6 in both games (on a 1-7 scale).

In order to determine whether or not the order of play had an effect on the scores in the second game, the sample was divided into two groups (children who used the real game first and children who used the AR game first) and Student t tests for the scores given to all questions were applied. No significant statistical differences were found.

For the following question: Which game did you like the most?. The majority of the children, 81%, preferred the AR game. Several explanations that the children gave for preferring the AR game were: 1) Because there was a robot that talked to me; 2) Because the cards (markers) were magic (most of the children gave this answer). With regard to the final question, F3, several comments were: 1) I liked these games because they can help me with my homework. 2) I would like to have this game at home in order to play with it (several children add this comment). 3) There have been a very interesting games.

The person in charge of the study added the following comments: 1) The children showed happiness when the robot congratulated them for chosing the right letter. This reaction was not the same when the person in charge of the study told them the same sentences as the robot did. 2) The children that preferred the AR game answered immediatly after the related question (F1), but the children that preferred the real game gave the answer after thinking for a while.

Figure 8 shows the room where the study was carried out and the elements used for the AR game and the real game. Figure 9 shows a child playing the AR game.

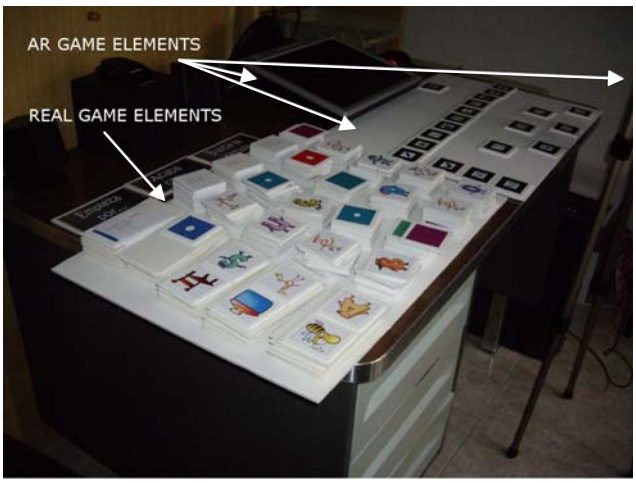

Figure 8. Elements of the AR game and the real game

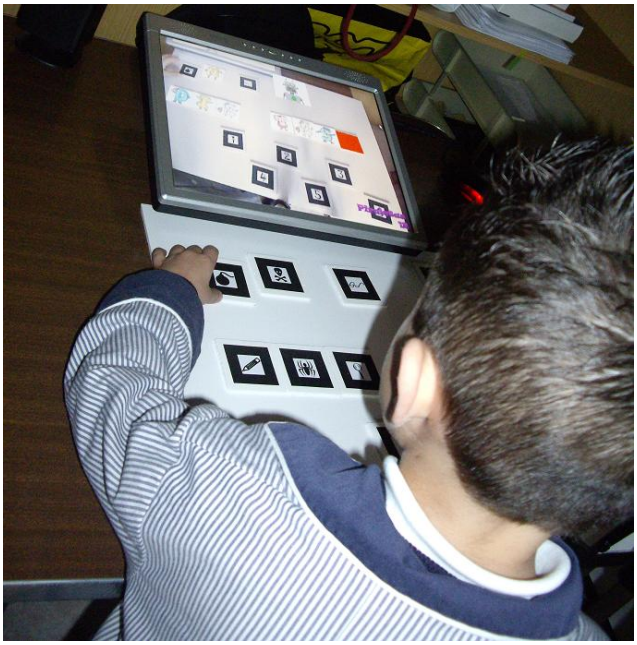

Figure 9. Child playing the AR game

IV. CONCLUSIONS

We have presented an AR game for learning words. Thirty-two children used the game. To our knowledge, this is the first AR game with these characteristics that has been developed and evaluated for learning words.

We have evaluated different aspects that are normally used in the evaluation of educational systems (technical, orientational, affective, cognitive and pedagogical). First, for the technical aspect, we evaluated usability (AG3, AG4). With regard to the easiness of use of the two games, the children did not found significance differences between the two games. Second, for the affective aspect (AG1, AG2, AG5, AG8), the results indicate that the children did not found significant differences between the two games. Third, for the cognitive aspect (AG7, AG9), again, children did not found significant differences between the two games. Fourth, for the orientational aspect (AG6), the children found significant differences between the two games. The mean of the real game was 1.25 higher than the mean assigned to the AR game. Finally, for the pedagogical aspect (AG10), again, children did not found significant differences between the two games. The scores assigned to AG10 were very high (AR, 6.72; real, 6.78). Therefore, at least children's opinion is that they have learnt with the games. Nevertheless, this opinion could not reflect totally the reality and a verification of the real improvement of knowledge should be considered in future studies. To summarize, the results indicate that the AR game has been positive accepted by children (81% preferred it) and related to the several evaluated aspects, children did not found significant difference between the two games. Therefore, the AR game could be a useful tool for learning words. Nevertheless, a more exhaustive evaluation could be performed.

The game can be improved in several ways. First of all, the game could be extended grouping the words, such as colours, food, etc. Second, the game has been developed for Spanish, but it can also be used for learning other languages, or even for learning foreign languages. Finally, the game can also be extended to other subjects such as mathematics, learning the numbers, the operations, etc.

Now, we are developing new AR games for edutainment thanks to APRENDRA project and the UPV project (PAID09015). With these projects, we hope to contibute with new games, new AR devices and/or new interfaces.

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REFERENCES

[1] Bimber, O., Fröhlich, D., Schmalstieg, D., Encarnaçao, L.M. (2001). The virtual Showcase, IEEE Computer Graphics & Applications, 21 (6), 48-55.

[2] Shelton, B.E., Hedley, N.R. (2002). Using Augmented Reality for Teaching earth-sun relationships to undergraduate geography students, First IEEE International Augmented Reality Toolkit Workshop, Darmstadt, Germany, http://depts.washington.edu/pettt/papers/shelton-hedley-art02.pdf.

[3] Kaufmann, H. (2004). Geometry Education with Augmented Reality, PhD Dissertation thesis, Vienna University of Technology.

[4] Woods, E., Billinghurst, M., Looser, J., Aldridge, G., Brown, D., Garrie, B., Nelles, C. (2004). Augmenting the science centre and museum experience, GRAPHITE, 230-236.

[5] Fjeld, M., Fredriksson, J., Ejdestig, M., Duca, F., Bötschi, K., Voegtli, B.M., Juchli, P. (2007). Tangible User Interface for Chemistry Education: Comparative Evaluation and Re-Design, CHI 2007, 805-808.

[6] Juan. M.C., Beatrice, F., Cano, J. (2008). Augmented Reality for learning the interior of the Human Body, IEEE International Conference on Advanced Learning Technologies Learning technologies in the Information society (ICALT'08), 186-188.

[7] Mei-Ling, C.L., Theng, Y, Liu, W., Cheok, A. (2008). A User Acceptance Study on a Plant Mixed Reality System for Primary School Children, Ubiquitous Computing, Design, Implementation and Usability, Ed. IGI Global, 87-98.

[8] Kato, H., Billinghurst, M. (1999). Marker tracking and HMD calibration for a video-based augmented reality, 2nd IEEE and ACM International Workshop on Augmented Reality (IWAR'99), 85-94, http://www.hitl.washington.edu/artoolkit.