Using an Augmented Reality game to find matching pairs

M. Carmen Juan; Marta Carrizo; Francisco Abad
Instituto ai2
Universitat Politècnica de València
Camino de Vera, s/n. 46022
Valencia, Spain

Miguelón Giménez
Escola d'Estiu
Universitat Politècnica de València
Camino de Vera, s/n. 46022
Valencia, Spain

ABSTRACT

In this paper we present an Augmented Reality (AR) game for finding matching pairs to learn about endangered animals in a fun way. Thirty-one children participated in a study. These children played the AR game and the equivalent real game. We have compared the results of the two games. We have evaluated different aspects (technical, orientational, affective, cognitive and pedagogical). The results indicate that children enjoyed playing the AR game more than playing the real game and that they perceived the AR game to be more fun than the real game. The children preferred the AR game to the real one and also seemed to learn about the subject of endangered animals.

Keywords

Augmented Reality, edutainment, finding pairs.

1. INTRODUCTION

In this paper, we present an Augmented Reality (AR) game for finding matching pairs. In an AR system, users see an image composed of a real image and virtual elements that are superimposed over it. The most important aspect in AR is that the virtual elements add relevant and helpful information to the real scene.

Our AR game follows the rules and appearance of the popular pair game. Since the game uses AR, over the pieces of the game can appear images as well as explanatory videos about the endangered animals. The animals and part of the information related to them were chosen from the Red List of Threatened species (http://www. iucnredlist.org) published by the International Union for the Conservation of Nature and Natural Resources (IUCN). This list was created in 1963 and is the world's most comprehensive inventory of the global conservation status of plant and animal species. The information on the Red List is updated on the web site whenever possible (annually). A full analysis of the data on the Red List is published once every four years. There are nine categories on the IUCN Red List: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient, and Not Evaluated. In this paper only two of these categories are described (critically endangered and vulnerable). Critically endangered, is defined as a species that is facing an 'extremely high risk' of extinction in the wild. Vulnerable, is defined as a species that is facing a 'high risk' of extinction in the wild.

The main objective of this work was to develop an innovative AR system to allow children to learn about the animals that are at risk of extinction in a fun way. The system is fun because it is played as a game. It is innovative because as far as we know there is no other AR system that has been developed for this purpose. Another objective was to evaluate different aspects of the AR game.

Taking into account the multidimensionality of learning as well as AR as a field, there are a number of technical, orientational, affective, cognitive, pedagogical and other aspects that can be considered in the evaluation. The technical aspect examines usability issues, regarding interface, physical problems, and system hardware and software. The orientation aspect focuses on the relationship of the user and the augmented environment; it includes navigation, spatial orientation, presence and immersion, and feedback issues. The affective parameter evaluates the user's engagement, likes and dislikes, and confidence in the virtual environment. The cognitive aspect identifies any improvement of the subject's internal concepts through this learning experience. Finally, the pedagogical aspect concerns the teaching approach: how to effectively gain knowledge about the environment and the concepts that are being taught.

This paper is organized as follow. Section 2 focuses on AR systems that have been used for learning. Section 3 presents our AR system and includes the software and hardware requirements as well as a description of the game. Section 4 presents the results of the game evaluation for the different aspects: technical, orientational, affective, cognitive and pedagogical. Finally, in section 6, we present our conclusions, our suggestions for improvements and future work.

2. RELATED WORK

Our work is not the first application for learning. Learning is one of the fields were AR has already been applied. For example, HIT Lab NZ (www.hitlabnz.org), University of Canterbury, New Zealand has developed several AR systems. The first one was The Magic Book [Bil01]. The Magic Book was presented as an example of an ARToolKit application. It looked like a normal book, but there were markers on the pages. A marker is a white square with a black border inside that contains symbols or letter/s. When the system recognized a marker, an image was shown or a story was started. Books of this type can be used for other purposes. A second work presented by this group was the S.O.L.A.R system. It was created for the TeManawa Science Centre (Palmerston North, New Zealand). It was an AR system for learning the position of each planet in the Solar System [Woo04]. A third work that is worthy of mention is the AR Volcano. It was developed for Science Alive! (Christchurch, New Zealand). It was a system for learning about volcanoes [Woo04]. Another work developed by this group was the BlackMagic. It was developed for the Telecom Technology Pavilion at the America's cup in New Zealand in 2003. It was a MagicBook that told the history of the America's Cup [Woo04].

Another research group that has also developed several AR systems in this field is the Mixed Reality Lab of Singapore (www.mixedrealitylab.org). They have developed several AR systems which include: the sun system, how plants grow and the Magic Story Cube. In the sun system, several concepts that are related to the solar system were explained. In the plant system children learned how plants germinate, disperse, reproduce and perform photosynthesis. The Magic Story Cube used a cube as a tangible interface that was folded or unfolded and, depending on the markers that were visible, the story was different. The Magic Story Cube presented the story of Noah's ark.

Other groups have also been working on the development of different AR systems. For example, Bimber et al. [Bim01] presented the Virtual Showcase. It 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 [She02] developed an AR system to teach the relation between the earth and the sun to geography students. In 2004, Kaufmann [Kau04] presented Construct3D as his PhD dissertation thesis. Construct3D was an AR system for constructing 3D geometries. It was designed to teach mathematics and geometry. Construct3D was tested with 14 students from two high schools in Vienna. The results from two evaluations showed that Construct3D was easy to use, required little time to learn, and encouraged learners to explore geometry. Larsen et al. [Lar05] presented an AR system for learning how to play billiards. The most outstanding characteristic of this system was that the game was played on a real billiard table. Organic chemistry can also be taught using an AR system [Fje07]. Fjeld's system, users interacted directly with 3D molecular models. In 2008, Sykora et al. [Syk08] presented a colour ball tracking that was used for direct manipulation with real objects. They presented two learning applications. The first one for learning basic principles of chemical reactions. Color balls were used to represent atoms. They combined typical AR markers with the color ball tracking that had a special semantic meaning. The second one for learning organs in a human body where the balls were used as a pointing device.

Our work is neither the first work that compared different presentation forms, for example Despina et al. [Des10] compared six different types of museum exhibits, one traditional and five interactive ICT exhibits. The exhibits were: a traditional map learning activity, a virtual tour projection, a multi-touch table application and three different AR applications (AR puzzle, AR map and Touch History). They evaluated the experience of young users with the exhibits. They included two questions. From the question: "your experience from the exhibit was (awful, not very good, good, really good, and brilliant)". Related to the brilliant score category, the touch table scored 76%, followed by the AR puzzle with a score of 67%, followed by the Virtual Reality tour and AR Map (with scores near 50%). They concluded that the experience scores top marks for the interactive ICT systems.

3. DESCRIPTION OF THE AR GAME

In our AR game, over the markers appeared images (Figure 1) and videos of endangered animals such as the Iberian lynx. The videos of the animals described the physical characteristics of the animal, its habitat and food, and also explained the causes of its possible extinction. The animals and the categories that were included in the game were the following:

- Critically endangered: Iberian lynx, Lowland gorilla, Red wolf, Orinoco crocodile, and Javan rhinoceros.
- Vulnerable: Polar bear, Iberian eagle, Humpback whale, and Amazonian manatee.

Figure 1. Looking for a pair

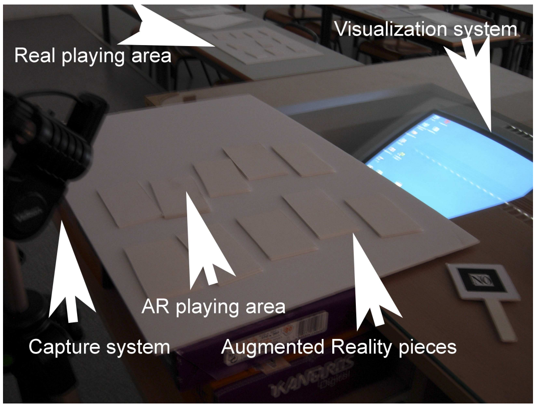

Figure 2. Elements used in the game

For the interaction with the game, the child only has to use markers with different symbols in their interior. In our work, we have not used a direct augmentation. The markers are a kind of a "remote control", but they are not directly augmented. The augmentation can be seen on the screen next to the playing area. That is, the child can see the real markers in front of him/her (playing area) and next to it, the screen with the augmented scene. Figure 2 shows the elements used in the game. The basic steps in the AR game are:

1) Initialization of the video entry and download of the files that contain the pattern and camera data, the XML files containing information related to the animals that are going to be shown.
2) The game asks the child to find the first animal pair. The child turns over one piece and then turns another one over.
3) The system identifies the visible markers and shows the related animal over them. The person in charge of the test must make sure that the child only turns over two pieces at a time. If the two markers belong to the desired animal, the game detects this situation and congratulates the child by telling that s/he has found the right animal. If the markers do not match, the child must continue to turn pieces over. Figure 1 shows an image where the child did not find a pair and s/he had to continue turning pieces over. The children could hold the pieces in their hands and look closely at the images.
4) If the child finds the right animal, the game asks if s/he wants to know more about the animal. The child has to use a marker with 'Yes' in its interior for answering yes, and a marker with 'No' in its interior for answering no. S/he has to place the chosen marker in a visible area in order to continue with the game. To facilitate the interaction, the child used a palette with 'No' in one side and 'Yes' on the another side. This palette can be seen in the left-lower area of Figure 2. If the answer is yes, the game shows a video over the visible marker/s. It shows the characteristics of the animal and explains the causes for its possible extinction.
5) The child can skip the rest of the video by using a marker with the symbol "*" at any point. For using this symbol, the child used another palette.
6) The game asks if the child wants to search for another animal. If the answer is yes, the game repeats step 2; if the answer is no, the game ends. The way of answering is the same as in step 4 (marker with 'yes'/'no').
7) At the end of the game, the child receives a score that depends on the number of animals successfully matched and the amount of time. The greater the number of matched pairs and the lower the time, the higher the score. The children's score is then compared with the ten best scores that are stored in an XML file.

In order to be able to extend the game to other themes with minimum changes, we included as much information as possible in XML external files. We used two different kinds of XML files. One of them contained the identification number of the image, the name of the animal, the length of the video, and the path to obtain the related images and videos. Another

XML file contained the total number of pairs available and also which ones were going to be used in each game. Another XML file was used to store the children's scores. For our game, we had a total of 10 animals. The ten markers used for showing animals are depicted in Figure 3. Figure 4 shows a boy playing with the AR game.

In order to validate the AR game, we compare it with a real game. The basic steps for playing with the real game are the following:

1) The child sits in front of the table for playing the real game (Figure 2, real playing area). The person in charge of the validation asks the participant to find a pair. The participant uses real pieces to find a pair. Figure 5 shows the pieces of the real game.

2) The participant turns over two pieces to find a pair. If the participant does not find a pair, the person in charge of the validation tells the participant to try again. If the participant finds a pair, the person in charge of the validation asks if the participant wants to know more about the animal. If the answer is no (verbally), the game goes to step, 3. If the answer is yes (verbally), the person in charge of the validation shows a page with images and text. The text is the same as the narrative of the video that is reproduced in the AR game. It explains the characteristics of the animal, its habitat and food, and it also explains the causes of the animal's possible extinction.

3) The person in charge of the validation asks if the participant wants to search for another pair. If the answer is yes, the game repeats step 1; if the answer is no, the game ends.

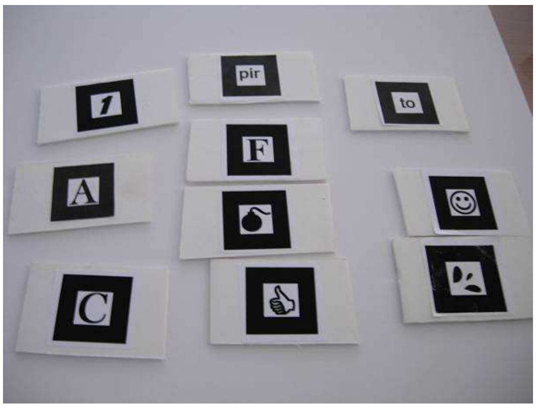

Figure 3. Markers used in the game

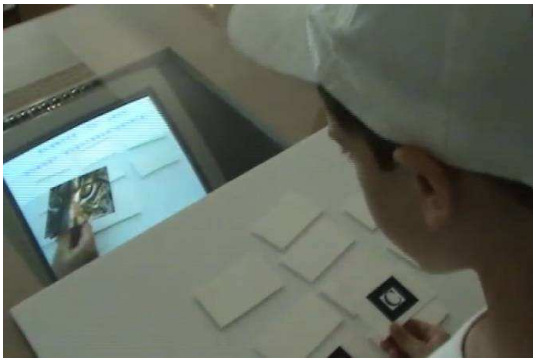

Figure 4. A boy is watching the video of the Iberian lynx

To capture the video, we used QuickCam Pro for Notebooks. The camera was fixed to a tripod which was placed next to the child. We used a table with back-projection as visualization system (a table made of glass under which a CRT monitor was placed). Figure 2 shows this table and its location.

To develop the system, we used the OsgART library (www.artoolworks.com/community/osgart). It is a C++ library that allows developers to build AR applications using the rendering capabilities of Open Scene Graph (OSG) and the tracking and registration algorithms of ARToolKit [Kat99]. OSG is a set of open source libraries that primarily provides scene management and graphics rendering optimization functionality to applications. It is written in portable ANSI C++ and uses the standard OpenGL low-level graphics API. ARToolKit is an open source vision tracking library that allows a wide range of AR applications to be easily developed. The required elements for the application are: a USB or FireWire camera, and a marker.

The animals' videos used in the game used AVI format. Their length ranged from 45 second to 1 minute. The animals' images were saved using the JPEG image file format.

Figure 5. The pieces of the real game

4. STUDY AND RESULTS

As stated in the section 1, one of the objectives of this work was to evaluate different aspects of the AR game: technical, orientational, affective, cognitive and pedagogical. To do this, we compared subjective measures taken in a real game and in the AR game.

The study included 31 children, 17 boys and 14 girls (aged from 6 to 12 years old, mean=7.7, SD=2.1). The children's parents signed an agreement to allow them to participate in this study

Children were counterbalanced and assigned to one of two conditions: a) Children who used the real game first and then the AR game, 15 children; b) Children who used the AR game first and then the real game, 16 children.

The protocol was the following. Before using either game the children were asked to fill out an entry questionnaire (appendix, Table 3). Then, the children were shown an explanatory video about the Red List of threatened species of the IUCN and also told how to play the games. This part was easy because most of the children already knew how to play to this popular matching game. The children then played the first game. After the game, the children were asked to fill out a post-game questionnaire (appendix, Table 4) and a reduced version of the presence questionnaire (appendix, Table 5) by Slater et al. [Sla94]. After filling out the two questionnaires the children played the second game. After playing, the children were again asked to fill out the post-game questionnaire and the same presence questionnaire. Finally, they were asked to fill out a final questionnaire (appendix, Table 6). 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 significance level was set to 0.05 in all tests. Table 1 shows paired t-tests for the scores given to the post-game questionnaire after playing both games. As this table shows, there was a statistical difference for questions 1 to 4. This indicates that children enjoyed playing the AR game more than playing the real game. They perceived the AR game as being more fun than the real game. Question 4 for the perceived value indicates that children preferred the AR game. Question 5 was also included to determine the perceived value, and there was no statistical difference between the two games. On the other hand, the children perceived the real game as being easier to play. There was no statistical difference between the two games for questions 5 to 9, indicating that the two games induced similar motivation and intention to change.

	AG1	AG2	AG3	AG4	AG5
AR	6.74(0.77)	6.58(1.23)	5.74(1.63)	6.55(1.23)	6.29(1.53)
Real	6.06(1.00)	5.90(1.25)	6.77(0.50)	5.90(1.51)	6.19(1.42)
t	4.33**	3.02**	-3.79**	3.07**	0.45
p	<0.001**	0.005**	0.001**	0.005**	0.655

	AG6	AG7	AG8	AG9
AR	6.97(0.18)	6.87(0.34)	5.90(1.70)	6.42(0.81)
Real	6.94(0.25)	6.84(0.37)	5.84(1.66)	6.36(0.80)
t	1	0.57	0.57	1.44
p	0.325	0.572	0.572	0.161

Table 1. Means (SD) of the AR game and the real game, and paired t-test of the post-game questionnaire, d.f. 30, **' indicates significant differences

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, this indicates that the order of play did not influence the children's scores for the post-game questionnaire.

To determine the level of perceived learning we compared the initial score for the children's knowledge about the animals that are at risk of extinction and the causes (I1, mean(SD)=3.45(1.183)) with the perceived learning scores after playing the two games (A2P1, mean(SD)=6.10(0.98)). Using paired t-test, $t(30)=-12.90$, $p<0.001$, the results show that there was a significant statistical difference between the two scores. The data indicate that children seem to learn using the games.

We analyzed the questions that related to the children's attitude using paired t-tests. We used I2 and AG6. Our analysis starts with the first group that used the AR game first and then the real one. In this case, the initial score for question I2 was very high, mean(SD)=6.69(0.79). This implies that even before playing either game the children thought we should provide greater protection to animals that are at risk of extinction in order to prevent their extinction. We compared the initial values with the values given after playing a game (AR/real). For the AR game, mean(SD)=7.00(0.00), $t(15)=-1.58$, $p=0.136$. The data show there is no statistical difference between the two values. The mean and standard deviation after playing the real game (after the AR game) was exactly the same. With regard to the second group, that is, children who played the real game first and then the AR one, the initial score was also very high for question I2, mean(SD)=6.87(0.35). Playing the AR game second, the values are the following, mean(SD)=6.93(0.26), t(14)=-1, p=0.334. The mean and standard deviation after using the real game first was the same as the initial score. Again, there was no statistical difference for the group who played the AR game after the real game.

We analyzed the questions related to the children's motivation to change. We used I3 and AG7, and paired t-tests. Our analysis starts with the first group that played the AR game first and then the real one. In this case, the initial score for question I3 was very high, mean(SD)= 6.56(0.89). As in previous analysis, even before playing either game, the children were willing to support initiatives to protect animals that are at risk of extinction (AG7). We compared the initial values with the values given after playing a game (AR/real). Playing the AR game first, the values are the following, t(15)=-1.70, p=0.111. As can be deduced from the data, there is no statistical difference between the two values. Again, as in previous analysis, the mean and standard deviation after playing the real game second was exactly the same. For the children who played the real game first and then the AR one, the initial score was also very high for question I3, mean(SD)=6.87(0.35). After playing the real game first, the values were: mean(SD)=6.73(0.46), t(14)= 1.47, p=0.164. After playing the AR game second, the values were: mean(SD)=6.80(0.41), t(14)=1.00, p=0.334. For the second group there was no statistical difference since the initial value was so high, the values after playing both games were slightly lower.

In our study, we used two questions for the sense of presence (the presence score is taken as the number of answers that have a score of 6 or 7). The scoring was on a scale of 1-7. The SUS Count indicates the mean of the test count of scores of 6 or 7 for the 2 questions. The SUS Mean uses the mean score across the 2 questions instead. For the AR game, these values are: SUS Count=1.90(0.40), SUS Mean=6.69(0.64). From these data, it is possible to deduce that the AR game induces a great sense of presence. Table 2 presents the rest of the data for the presence questionnaire. It shows paired t-tests for the scores given after playing the two games. The analysis of the data indicates there is no significant statistical difference between the two games. This implies that children perceived the AR game as being real. In order to determine whether or not the order of play had effect on the scores in the second game, the sample was divided into two groups (the group of children who played the real game first and the group of children who played the AR game first). Student t tests for the scores given to all questions were applied. No significant statistical differences were found. Therefore, the order of play did not influence the children's scores for the presence questionnaire.

Figure 6 presents the results for the question AP2. Figure 7 shows children's preferences grouped by age. The majority of the children preferred the AR game. For the older children, this percentage was higher. Several explanations that the children gave for preferring the AR game were: 1) There were videos; 2) I could move the videos on the computer; 3) The videos explained much better why the animals are at risk of extinction; 4) You learn more with the videos; 5) Because I really liked the videos that I saw; 6) Because I could see my hands in the image. However, there were some children who liked the real game better. For the following: Because it was easier.

	P1	P2
AR	6.71(0.64)	6.68(0.70)
Real	6.90(0.30)	6.87(0.34)
t	-1.99	-1.65
P	0.056	0.110

Table 2. Means (SD) of the AR game and the real game, and paired t-tests for scores given to the presence questionnaire after playing the two games, d.f. 30

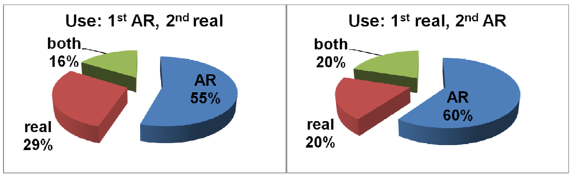

Figure 6. Children's preferences

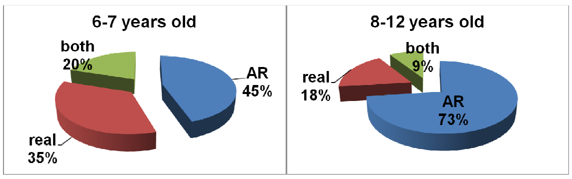

Figure 7. Children's preferences grouped by age

Some positive comments related to the AR game were the following: 1) I will talk with my sister who is a biologist and I will tell her about everything that I have learned; 2) This game has surprised me; 3) I enjoyed seeing the images and videos presented this way.

The only negative comments were the following: 1) I am not interested in the videos and I do not want to listen; 2) I do not like the game because for me it is not a game, it is another way of learning; 3) I don't feel like playing.

5. CONCLUSIONS

We have presented an AR game that implements a popular pair game for learning about different animals that are at risk of extinction. The children learn the animals' habits, characteristics, and the causes of possible extinction. Thirty-one children played the AR game and the equivalent real game. To our knowledge, this is the first AR game with these characteristics that has been developed and evaluated for learning.

We have evaluated the aspects that are normally used in the evaluation of educational systems (technical, orientational, affective, cognitive and pedagogical). The results indicate that children enjoyed playing the AR game more than playing the real game and that they perceived the AR game to be more fun than the real game. With regard to presence, the questionnaires indicated that the AR game induced sense of presence in children and that this sense of presence was similar to what they felt in a real environment. Analyzing preference by age, it can be deduced that older children liked the AR game more than the younger ones. If attitude and motivation to change are considerer, the results indicate the following. Before playing either game the children thought 'We should provide greater protection to animals that are at risk of extinction in order to prevent their extinction'. In this case, the results indicate that the children's attitude did not change after playing the games. Before playing either game, the children were also willing to support initiatives to protect animals that are at risk of extinction. As in the previous case, the results indicate that the children's motivation to change did not change.

These results are encouraging, because AR has demonstrated that the children have fun and enjoyment; and induce sense of presence. Also before using either game, the children thought that "We should provide greater protection to animals that are at risk of extinction in order to prevent their extinction". In spite of this, they perceived more value in the AR game than in the real game.

More work has to be done to evaluate educational AR systems. We have evaluated some parameters of the different evaluation aspects, but a more exhaustive evaluation could be performed. This would provide a more significant contribution to educational systems, particularly AR educational systems.

The system can be improved in several ways. First of all, the glass surface on the table reflected. This problem could be solved using a non-reflecting glass surface or by eliminating it completely. We placed the camera on a tripod next to the child, but a more stable element could be used instead. Second, another improvement that would involve greater changes is to convert the system from 2D to a 3D version. Related to the 3D version, if models of 3D animals with a significant number of polygons were used, the rendering speed would be an important aspect to evaluate. In that case, modern Graphics Processing Units could be exploited for accelerating the rendering rates. Also, the current parallel computing methods and multi-core methods could be further used for achieving such acceleration. Third, with these ideas, it would be possible to teach/learn other subjects, such as animals/plants/etc. using different methods for classification. Changing these features is especially easy in our system because of its structure. The system could be used for other purposes and the results could be compared with the ones obtained in this work. Fourth, in order to evaluate the acquired knowledge of players, a final examination could also be included.

Now, we are developing new AR games for edutainment thanks to APRENDRA project. With it, we hope to contribute with new games, new devices that incorporate AR, new interfaces and validations with enough number of children for obtaining statistical significant results.

Finally, we firmly believe that AR has great potential in the educational field. Our results as well as those by other researchers (e. g. [Kau04]) should encourage the AR community to develop and evaluate new AR systems.

6. ACKNOWLEDGMENTS

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APPENDIX

Question ID	Questions
I1	How much do you know about the animals that are at risk of extinction and the causes for this?
I2	Please, indicate the value that best describes your opinion with respect to: "We should provide greater protection to animals that are at risk of extinction in order to prevent their extinction"
I3	Please, indicate to what extent you would be willing to support initiatives to protect animals that are at risk of extinction?

Table 3. Entry questionnaire

Question ID	Questions
AG1	***Engagement and fun*** I enjoyed playing this game.
AG2	This game has been fun
AG3	***Easy to use*** Has it been easy to play?
AG4	***Perceived value*** I think playing this game can help me to learn the animals that are at risk of extinction
AG5	I would like to play again because it is interesting for me
AG6	***Attitudes*** Please, indicate the value that best describes your opinion with respect to: "We should provide greater protection to animals that are at risk of extinction in order to prevent their extinction"
AG7	***Motivation to change*** Please, indicate to what extent you would be willing to support initiatives to protect animals that are at risk of extinction?
AG8	***Intention to change*** As a result of playing this game, I will talk with my friends and relatives about the animals that are at risk of extinction
AG9	As a result of playing this game, I will think more about the animals that are at risk of extinction and the causes for this

Table 4. Post questionnaire

Question ID	Questions
P1	Have you had the sensation of playing with pieces where images and videos appeared over them (AR system)?
P2	Were there moments during the game when you thought that the images over the pieces were real?

Table 5. Presence questionnaire

Question ID	Questions
AP1	How much have you learned about the animals that are at risk of extinction and the causes for this?
AP2	Which game did you like the most?
AP3	Why?
AP4	Add any comment about the experience

Table 6. Final questionnaire