ARGreenet and BasicGreenet: Two mobile games for learning how to recycle

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ABSTRACT

In this paper, a new Augmented Reality (AR) mobile phone game 'ARGreenet' is presented. The game aims to raise individuals' awareness of the importance of recycling and teaching participants how to do it. In this research, the 'ARGreenet' is compared with a similar 'Basic' mobile phone game for recycling. Thirty eight children aged from 8 to 13 years of age participated in this study. To quantify aspects of the utility and effectiveness of the games, the children answered questionnaires both before and after using each game. Aspects examined included the level of engagement and fun of each game, the ease of use and perceived value of each game, and the perceived learning about recycling. We report a positive change in intended behavior with both games. The results suggest that playing both games is likely to have a positive influence in changing participants' recycling behaviour. These preliminary results also suggest that the mobile phone is potentially a good platform for not only learning about recycling but also influencing people to change their behaviour. A majority of the participants expressed a preference for ARGreenet game. They perceived it as easy to use and more engaging and fun than the BasicGreenet game.

Keywords

Augmented Reality, mobile phones, recycling, behaviour change, learning.

1. INTRODUCTION

It is now widely accepted that anthropogenic actions are a major cause of the rising CO_2 levels in the earth's atmosphere (IPCC, Fourth Assessment Report. Intergovernmental Panel on Climate Change, 2007). Linked to this are human consumption patterns that generate enormous volumes of waste, particularly in developed countries. The waste problem has been recognised by world leaders for some time. Significant recognition was given to the problem as part of the Agenda 21 for sustainable development – an action plan devised at the Earth Summit held in Rio de Janeiro (1992). In 2005, the European Landfill Directive sets targets to minimise waste to landfill through increased levels of recycling and recovery and the EU's Sixth Environment Action Programme identifies waste prevention and management as one of its top four priorities. As a result all member states of the European Union are implementing a number of waste management systems.

This paper reports on an Augmented Reality (AR) mobile phone game which aims to educate the user on how to recycle their waste effectively. AR refers to the introduction of virtual content into the real world. The AR game (ARGreenet) is presented alongside a basic game (BasicGreenet) that shared the same purpose. The aim of the research was to test the hypothesis that the ARGreenet would have greater influence on a number of variables than the BasicGreenet.

2. PREVIOUS WORK

Augmented Reality

AR systems running on PCs have been designed for their application in many fields including: medicine; military; robotic; maintenance and repair applications; learning; entertainment or edutainment; [Azu97] [Azu01]. However, with the advent of portable computers and notebooks, mobile AR became possible and later, different applications for PDA's and mobile phones were developed for their

application in several fields such as learning (e.g. [Liu07] [Wan09]), edutainment (e.g. [Wag07a]), etc.

Related to learning, systems for learning subjects as different as English [Liu07] or heritage temples [Wan09] have been presented. Li et al. [Liu07] developed a handheld AR system for learning English called HELLO based on 2D barcodes. A four-week pilot study was conducted and the results indicated that 2D barcodes and AR were useful for English learning. Wang et al. [Wan09] tested three user interface prototypes for learning heritage temples. Their study showed that users preferred animated and interactive virtual elements with sound effects, and that the superimposed information should not cover more than 30% of the screen.

Related to edutainment (term that points out the connections and the positive correlations between the educational field and the entertainment one), an example could be the Virtuoso Arts History Game [Wag07a]. It is a collaborative educational game for up to four players. The players' objective is to sort a collection of artworks. A virtual animated character called Mr. Virtuoso can provide help for players that are stuck. Another example could be Alien Contact! [Osh09] that was the first game developed in the Handheld Augmented Reality Project (HARP), http://isites.harvard.edu/harp. In Alien Contact!, participants use GPS-enabled handheld computing units. Alien Contact! is based on a scenario where aliens have crash landed. Students work in teams, and learn math and literacy skills.

Finally, with the appearance of the iPhone, different AR applications have been presented for this device. Several of them can be downloaded from the Apple Store.

Enhancing recycling behaviours

As this paper focuses on bringing about behaviour change it is useful to examine the theoretical constructs which helped to inform the research design of the AR waste management game. The Theory of Reasoned Action is a useful theoretical construct for designing processes to enhance recycling behaviours because it is strongly dependent on the concept of behavioural intention – the commitment to a certain action or behaviour [Ajz80]. The theory asserts that behaviour is a deliberate act based on the beliefs of the individual and the norms imposed by society [Ton04]. Therefore, when an individual is positively predisposed toward a particular behaviour, and when they perceive support for that behaviour from people around them, then they will form a positive behavioural intention towards that behaviour. Behavioural intention, in turn, leads to actual performance of the relevant behaviour [Ajz80].

In the context of recycling behaviour, over the past decade there has been an increasing expectation for individuals to recycle their household rubbish. That is, a subjective norm exists that recycling is a reasonable thing to do, but this is unlikely on its own to produce recycling behaviour. However, if individuals also hold a positive attitude towards recycling they are more likely to actually perform the behaviour [Gar08].

The Theory of Reasoned Action was later modified to Ajzen's Theory of Planned Behaviour [Ajz91]. This theory incorporates the person's belief about how easy or difficult it is to perform a specific behaviour, based on their abilities, opportunities and resources [Gar08]. Because recycling requires enormous individual effort it is helpful to understand which characteristics will help them to make the decision to recycle more often [Bol95]. Within this research we examined participants' knowledge and attitudes towards recycling and the environment to identify if this impacted on their ability to perform the recycling behaviours required in the ARGreenet and BasicGreenet.

3. DESCRIPTION OF THE GAMES

ARGreenet

The objective of ARGreenet is that participants learn how to recycle effectively. ARGreenet uses markers (a white square with a black border containing symbols or letters). The player has to pick up objects that appear over the objects' marker and place them in the correct recycling bin. Only one object appears over the objects' marker at a time (e.g. Figure 1), but this object will vary at different stages of the game. The recycling bins appear over four different markers, with the following letters in their interior: A, B, C and G (e.g. Figure 2). The markers are independent and are placed over a table by the person in charge of the experiment. The markers can be placed on the floor or in any desired place. There are three different levels within the game. In the first level only two recycling bins and 2 objects randomly selected among 6 possibilities for each type of rubbish that appears. That is, over the objects' marker only two different types of rubbish appear and only two recycling bin markers are used, A and B. The two possible recycling bins appear over these markers (one recycling bin over A marker and the second recycling bin over B marker). In the second and third level more recycling bins and more objects appear, specifically, 3 and 4 recycling bins and 4 and 6 objects, respectively. That is, in the second level three recycling bin markers are used, A, B and C, and in the third level the four recycling bin markers are used. When the player correctly places the rubbish they are rewarded by the game showing two hands

applauding over the recycling bin. If the participant wrongly places the object, the game shows a red cross over the recycling bin.

The game applies the usual rules for games. A player gains or loses points for correctly or incorrectly recycling or leaving the rubbish outside the recycling bins. If the object has been correctly placed then the player gains points while on the contrary, the player loses points if incorrect. If the player is unsure about the correct recycling bin for a type of rubbish, he has the possibility to place the rubbish outside all recycling bins. In this case, the game subtracts points, but less than incorrectly placing the rubbish. The game goes to the next level when the player has achieved a fixed number of points for each level.

The game also has an allocated time for each level, if the player finishes before the allocated time, he gains 5 points for each second left. The game also includes a number of questions in each level that are randomly selected in each run. These questions are also related to recycling. The questions offer three possible answers of which only one is correct. The player has to choose among these three options. Again, the player gains points if he answers correctly or loses points if he answers incorrectly. The questions are stored in an XML file which facilitates the inclusion and removal of questions. The game records the top ten players' names which are stored in a file and can be consulted as an option of the game. The game also includes a help option where all the rules of the game are explained. Figures 1 and 2 show two images of the game. In Figure 1 is possible to see rubbish (a cardboard box) over the object marker. Figure 2 shows a step of the game where the player has placed rubbish over the correct recycling bin.

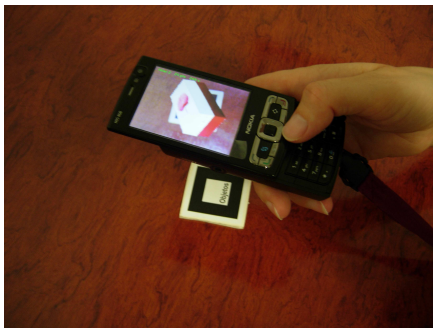

Figure 1. ARGreenet. Player is picking up a residue

For hardware the only required device is a mobile phone. This research used the Nokia N95 with 8GB. The most outstanding features of this mobile phone for AR are: Large 2.8" QVGA (240 x 320 pixels); Carl Zeiss Optics camera with 5 Megapixels; VGA video capture of up to 30 frames per second.

The software was distinguished, firstly, between the required development environment and the additional software for programming for the selected mobile phone in C++; and secondly, the library for the AR facilities. This research developed a system using Microsoft Visual Studio 2005. But for running an application simulating its running in the selected mobile phone, an emulator of the mobile phone is required. For including this type of tools the S60 Platform SDK, 3rd Edition was used. For programming in C++ for Symbiam OS it is also required the installation of Carbide.vs 3.0.1.

Figure 2. ARGreenet. Player has correctly placed a residue

For AR facilities the ARToolKit 2.65 [Kat99] was ported onto a mobile phone running on Symbian OS and Series60. In 2003, Wagner & Schmalstieg [Wag03] ported ARToolKit to Windows CE. In 2005, Henrysson et al. [Hen05] ported ARToolKit to the Symbian platform. Later, in 2007, Wagner & Schmalstieg [Wag07b] presented the ARToolKitPlus library for its use on mobile devices (e.g. PDA's). Studierstube Tracker [Sch07] was a posterior version of ARToolKitPlus. Another framework presented by Wagner and colleagues was Studierstube ES [Wag09]. For developing our AR library, we studied two possibilities. The first one was to port the well-known ARToolKit to mobile phones and later to incorporate additional functionalities. This portability has already been achieved successfully [Hen05] [Wag07b]. Therefore, we were sure it was possible. These were the only two previous experiences when we started our work and Henrysson et al.'s library was not freely available. The second one was to use the ARToolKitPlus and incorporate to it additional functionalities. The result of both developments should be similar. We decided to choose the first possibility because of our earlier experiences in modifying ARToolKit, for having more knowledge about the code and for possible improvements.

BasicGreenet

The objective of the BasicGreenet is the same as the ARGreenet. The recycling bins appear on the lower part of the screen and rubbish goes down from the top

of the screen. There are three different levels within the game as in ARGreenet. In the first level only two recycling bins appear in the lower part of the screen, and 2 objects randomly selected among 6 possibilities for each type of rubbish go down from the top of the screen. In the second and third level more recycling bins and more objects appear, specifically, 3 and 4 recycling bins and 4 and 6 objects, respectively. The player has to correctly place rubbish into the correct recycling bin by pressing the left/right keys on the mobile phone. If the player wants the rubbish to go down quickly, he can press the down key. If the player is not sure about the type of rubbish and the correct recycling bin to place it, he can place the rubbish outside any of the recycling bins. In this case, the game does not decrease points. The rules of the game and the points that the player gains or loses based on their different actions, are similar to ARGreenet described above. However, in this case the two animations for placing correctly/wrongly rubbish are not used. Instead of this, in the top left of the screen appears the level; in the top centre of the screen appears the consumed time in seconds of the current level; and in the top right appears the score achieved in the current level. Several question about recycling appear after the player has achieved an already - established score. If the player correctly places rubbish or answers correctly a recycling question, the score increases, if not, the score decreases. Figure 3 shows an image of this game in which it is possible to see the third level (recycling an apple core).

As hardware, the only required device is the same mobile phone that was used in the ARGreenet, the Nokia N95 with 8GB. In relation to the software NetBeans IDE 6.0.1 was used as the development environment. The language used for the development was Java, J2ME. The plug in Java ME Wireless Toolkit for CLDC was incorporated into the development environment to provide the required classes for loading/writing files in mobile devices.

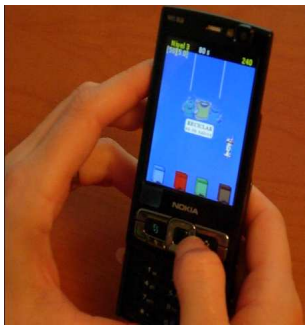

Figure 3. BasicGreenet. Third level

4. EXPERIMENTAL DESIGN AND MEASURES

The research experiment involved 38 children engaged in playing both the ARGreenet and BasicGreenet. All participants experienced both games but in a different order, with one group of participants experiencing the ARGreenet first, while the second group experienced the BasicGreenet first. Each group had 19 participants.

The research involved the children firstly completing an entry questionnaire (Table 1). This questionnaire includes questions about mobile phone experience, gaming experience, knowledge of recycling, beliefs about the environment/attitudes, behaviours, and intended behavior/motivation to change. In order to familiarize students with the elements that appear in either game the children would then spend time examining a page where the type of recycling boxes with their corresponding rubbish are shown. Once this was done the children participated in their first game, either ARGreenet or BasicGreenet, and completed a post questionnaire (Table 2). The students then repeated the process by familiarizing themselves with the elements of the second game, using the game and completing another post questionnaire. After playing the ARGreenet, the children were asked to complete two questions around presence which were “I had a sense of being in the room where there are rubbish and recycling boxes” and “There were times during the experience when I thought that objects and images were in the room, over the table or over my hand”. After playing both games, the children were asked to complete a final questionnaire (Table 3).

Quantitative data was collected using questionnaires. Because the target age group was young (< 15years) the questionnaire was kept short. All questions were measured on a 7 point Likert scale where in most cases 1 = none and 7 = a great deal. In the case where the meaning of 1-7 was different, the meaning is referred to in the related question.

In addition to basic demographic data including age and gender, there were a number of questions to investigate individuals’ experiences with mobile phones and the phone being used in the trial, followed by a question about the students’ levels of experience with gaming devices. Informed by the theories of reasoned action [Ajz80] and planned behaviour [Ajz91], further questions were asked to ascertain levels of participant knowledge of recycling, their attitudes towards recycling and the environment, current recycling behaviours and their perceived willingness to change the behaviours. The post game and final questionnaires are presented in Tables 2-3, with different aspects identified by different white/grey background colours.

Quest. ID	Questions	Mean(SD)
E1	***Mobile phone experience*** How much experience do you have using mobile phones	3.87(1.42)
E2	Please indicate your level of expertise with the Nokia N95 phone	1.05(0.23)
E3	***Gaming experience*** How much experience do you have in playing games on a PC or mobile phone?	4.74(1.74)
E4	***Knowledge of recycling*** How much do you know about what can be recycled and how to recycle?	4.97(0.91)
E5	How much do you know about the effect of recycling on your environmental footprint?	4.00(1.59)
E6	Please indicate your level of expertise in what recycling is and why recycling is important: (1-Novice, 7-Expert)	4.68(1.21)
E7	**Beliefs about the Environment/Attitudes** People should be recycling more in order to reduce their environmental footprint	6.47(0.92)
E8	***Behaviors*** I recycle my garbage and separate the cans, the bottles, newspapers etc.	5.18(1.18)
E9	***Intended behaviour/Motivation to change*** I am willing to taking new actions to improve my recycling behaviour. (1-would not accept, 7-would accept)	5.92(1.32)

Table 1. Entry questionnaire

Quest. ID	Questions
P1	***Engagement and fun*** I enjoyed playing this game.
P2	This game was fun
P3	***Easy to use*** Please indicate if the game has been easy to play (1-not easy, 7-very easy)
P4	***Perceived value*** I think playing this game could help me better recycle
P5	I would be willing to play this game again because it has some value to me
P6	***Attitudes*** How strongly do you agree with the following statement? People should be recycling more in order to reduce their environmental footprint. (1-strongly disagree, 7-strongly agree)
P7	***Intended behaviour/Motivation to change*** I am willing to taking new actions to improve my recycling behaviour. (1-would not accept, 7-would accept)
P8	***Intention to change*** As a result of playing this game I will talk to my friends and family members about recycling.
P9	As a result of playing this game I will think more about recycling and its effect on the environment.
P10	As a result of playing this game I will make changes to my current behavior

Table 2. Post questionnaire

Quest. ID	Questions
F1	***Perceived learning about recycling*** Please indicate the number that most closely describes how much you think you have learned as a result of playing these games How did you learn about what can be recycled and how to recycle? (1-nothing, 7-very much)
F2	Please indicate your level of expertise about the rubbish you can recycle as a result of playing these games (1-Novice, 7-Expert)
F3	***Preference*** Which game did you like the most? Normal game: AR game:
F4	Why?. Any comment that you like to add
F5	Any comment that you like to add

Table 3. Final questionnaire

Question	ARGreenet Post-test	BasicGreenet Post-test	t	p
P1	6.40(0.89)	6.29(0.80)	0.702	0.487
P2	6.18(1.01)	6.05(0.96)	0.777	0.442
P3	6.26(0.89)	5.79(1.19)	2.303**	0.027**
P4	6.53(0.80)	6.42(0.79)	1	0.324
P5	6.24(1.17)	6.00(1.19)	1.326	0.193
P6	6.82(0.46)	6.92(0.36)	-1.434	0.160

Question	ARGreenet Post-test	BasicGreenet Post-test	t	p
P7	6.45(0.83)	6.45(0.76)	0	1
P8	5.76(1.24)	5.87(1.02)	-1	0.324
P9	6.00(1.04)	6.18(0.83)	-1.641	0.109
P10	6.05(1.06)	6.13(1.12)	-0.723	0.474

Table 4. Means (SD) of the ARGreenet and the BasicGreenet, and paired t-test of post-test scores. d.f. 37, '' indicates significant differences**

5. RESULTS

The sample was comprised of thirty eight participants with a mean age of 10.76(1.49) years. Within the sample group there were more males (63.2%) than females represented.

From the entry questionnaire, means (SD) are in Table 1. From the these scores, we can deduce that participants reported to have relatively little mobile phone experience (E1), and considered themselves to be novices with the Nokia N95 (E2). Participants reported to have some experience with gaming (E3). Overall participants initially stated they had a moderately high knowledge of recycling (E4, E5 and E6). Furthermore most reported positive beliefs toward recycling (E7). The participants also reported a willingness to do more (E9), although the majority reported that they were already strong recyclers (E8).

Paired t-tests were applied to the scores given to all questions of the post questionnaire filled out after playing each game. These analyses are shown in Table 4. None of the statistical paired t-tests applied to the results showed significant differences between the two games except for question P3. The significance level was set to 0.05 in all tests. From this data, we can deduce that the two games were very positively accepted by the players. The combined mean among all the ten questions for the two games is 6.24(0.31). Moreover, the games had a very similar influence on responses with the actual difference between the mean responses being very small. From the findings the following, trends can be inferred:

- The BasicGreenet had a marginally, more positive influence on responses to the belief question (P6), and questions regarding intentions to change behaviours (P8-P10).
- The ARGreenet had a marginally more positive influence on responses to the engagement and fun questions (P1-P2), ease of use (P3), and the perceived value questions (P4-P5).
- Each game had a very similar influence on intended behaviour/motivation to change (P7).

In order to determine whether using either of the games first has any effect on the scores for the second game, the sample was divided into two groups: the participants who used the ARGreenet first; and the participants who used the BasicGreenet first. One-way ANOVA analyses were applied to the scores for all questions (20 in total). Only three of the statistical ANOVA tests applied to the results showed significant differences between the two games. From this data, we can deduce that the order of playing did not significantly affect the scores for the second game.

To confirm if participants changed their attitudes as result of playing the games the scores for question E7 and the related questions answered after playing both games (P6), were compared using paired t-tests. The results showed significant differences (for ARGreenet, $t(37)=-2.589$, $p=0.014$; for BasicGreenet, $t(37)=-2.903$, $p=0.006$; confirming that participants' attitudes have been influenced by the games. We also checked if participants' intentions to change behaviours were altered after playing the games. For this the scores for question E9 and the related questions answered after playing both games (P7), were compared using paired t-tests. Again, the results showed significant differences for ARGreenet, $t(37)=-2.603$, $p=0.013$; and for BasicGreenet, $t(37)=-2.477$, $p=0.018$. Therefore, participants' intentions to change behavior appear to have been influenced by the games.

For the relationship between the intended behavior before (E9) and after (P7) playing the games Pearson's correlation was used. The null hypothesis is that the correlation coefficient comes from a population in which the correlation is 0. In order to determine if the correlation is significant, we checked whether the correlation coefficient is within the sample distribution specified by the null hypothesis with different probabilities. The Pearson Correlations significance levels are shown in Table 5. Using the results from the game that was first used by each of the two groups of children (i.e. when ARGreenet is first used or when BasicGreenet is first used) we can deduce that ARGreenet presents a more significant correlation. These results confirm that a positive change in the intended behaviour has been brought about by using the games, especially the ARGreenet. Considering Gardner & Ashworth's [Gar08] advice that "if individuals also hold a positive attitude towards recycling they are more likely to actually perform the behaviour" and the results of the games' influence on players' attitudes and intended

behaviours, it appears they will most likely recycle better as a result of playing the games.

Game used	Order of use	Significance level
ARGreenet	First used	0.621(0.005)
BasicGreenet	First used	0.566(0.02)
ARGreenet	Used second	0.318(0.2)
BasicGreenet	Used second	0.361(0.2)

Table 5. Pearson Correlations significance levels

Checking if participants' perception for learning about recycling has been influenced by playing the games, the scores for question E6 and the question answered after playing both games (F2), were compared using paired t-tests. The results showed significant differences for all data, $t(37)=-5.011$, $p<0.001$; when ARGreenet is first used, $t(18)=-3.082$, $p=0.006$; and when BasicGreenet is first used, $t(18)=-4.135$, $p=0.001$). We also compared, using paired t-tests, the scores for question E4 and the question answered after playing both games (F1). The results showed significant differences for all data, $t(37)=-6.047$, $p<0.001$; when ARGreenet is first used, $t(18)=-4.324$, $p<0.001$; and when BasicGreenet is first used, $t(18)=-4.135$, $p=0.001$). Therefore, participants' perception for learning about recycling has been influenced by the games. Moreover, the mean (SD) of F1 scores were equal or more than 6 for all data, 6.05(0.84); when ARGreenet is first used, 6.00(0.67); and when BasicGreenet is first used, 6.11(0.99)) and so it is also possible to deduce that the players' feel that they have learnt about what can be recycled and how to recycle.

In our study, two questions relating to the sense of presence were included in the questionnaire asked at the end of playing the ARGreenet only. This questionnaire was based on the Slater et al. [Sla94] questionnaire. The first presence question was "I had a sense of being there in a room where there are rubbish and recycling boxes". Participants could answer from 1 = not at all to 7 = very much. The second questions was "There were times during the experiences when I thought that draws and images were in the room, over the table or over my hand" where 1 = at no time and 7 = almost all the time. The presence score or SUS Count is taken as the number of answers that have a score of 6 or 7. In our study, the SUS Count was 0.974(0.753). The SUS Mean across the two questions was 5(1.484) so although the presence scores were quite high, but they did not reach 6.

With regard to preferences, children answered to question F3. Most participants (69.4%) preferred the ARGreenet. When the BasicGreenet is first played, 82.4% of participants preferred the ARGreenet, whereas 57.9% of participants preferred the ARGreenet when the ARGreenet is first played.

Several explanations why the children gave their preference for the ARGreenet were: It was fun to have things over my hand that really they were not there; The AR game was more original; The AR game was more amusing; The AR game was more real; It is different to typical games.

However, there were some children who liked the BasicGreenet better who gave the following responses: I like playing remaining seated; I prefer to use the mobile with my hand rather than moving around the room; I prefer to use the keys of the mobile to play; Because in the Basic game the objects appear and you do not have to look for them.

A few children added some final comments in response to the question "Any comments that you like to add". These included: I want to know how the AR game works in order to explain to my parents; I propose to commercialize both games.

An observation remarked by the person in charge of the experiment was: "With the AR game, several children played with the markers placing them in different places (over their t-shirt, their cap, etc.)".

6. CONCLUSION

The results from our research show that the two games, ARGreenet and BasicGreenet have been very positively accepted by players with an overall mean of 6.24 (on a scale 1-7). The results did not show statistical significant differences between the two games. However, 69.4% of the participants preferred the ARGreenet game, they perceived it as easy to use and more engaging and fun than BasicGreenet. From our point of view, if a game is easy and fun to play, children will play it, and - consequently - the overall impact of the game on their behaviour will be much higher than in case of a game which is more difficult and less fun to play. From the results, there is not any statistical evidence that ARGreenet is perceived to be different from BasicGreenet, the majority of participants preferred the ARGreenet game and five of the ten analysed questions showed that ARGreenet offered greater means than the BasicGreenet game. While one question offered the same mean for both games. This implies that these preliminary results corroborate the hypothesis that the ARGreenet would have greater influence on a number of variables than the BasicGreenet. Based on the sense of presence questions our results suggest that participants experienced a moderately high sense of presence using ARGreenet.

From the analyses is also possible to infer that the games did influence the knowledge of participants, their attitudes and had a positive influence on their

intentions to change behaviours. Based on the advice of Gardner & Ashworth [Gar08] that "if individuals also hold a positive attitude towards recycling they are more likely to actually perform the behaviour", these results suggest that playing the games is likely to have some influence to change participants' behaviour. Future research could be conducted at a later stage to confirm if players' actual recycling behaviour has been positively affected.

All these conclusions suggest that the mobile phone is potentially a good platform not only for learning about recycling but also persuading people to change their behaviour, and that AR mobile phone applications is probably likely to be more positively received, particularly from a fun point of view. However, more experiments should be carried out in order to determine, first, if AR gaming is preferred to simple mobile games for edutainment in general; second, if educational games help children change their attitude towards recycling; third, if games are preferable to other forms of media, e.g. TV, etc.

The games and the trial can be improved in several ways. The games could incorporate more rubbish types apart from those already included, and more questions relating to these types of residues. The trial could also be improved by controlling the way in which the games are played. It would be useful to conduct a trial where all players start with the BasicGreenet and then graduate to the ARGreenet and then conduct another trial where only the ARGreenet game is used and compare the responses to questionnaires. A more extensive final questionnaire could be used to enable improved comparison between the two games. The trial could also be improved, especially, in the influence of learning of both games, including the related question after using both games. In order to evaluate the acquired knowledge of players, a final examination could also be included. It would also be possible to use another learning practice in which the knowledge would be presented in-game and let children learn through their engagement, e.g. an adventure game.

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