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http://dx.doi.org/10.1515/humaff-2019-0028

Promoting Pro-Environmental Behaviour through Augmented Reality and Persuasive Informational Power: A Pilot Study

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Abstract

This pilot study examined the idea that use of a mobile technology can have positive consequences for both individual users and, indirectly, for society. The augmented reality (AR) application used is defined as persuasive technology, because it is intended to modify users' attitude or behaviour.

The application was designed for personal use although it can generate indirect benefits for users' communities as well as for users themselves. The application was tested in a small sample, in a controlled setting in order to observe how it was used and evaluate its efficacy as a source of information and tool for persuasion. The results showed that opinions of the AR device were generally positive, moreover participants admitted that it improved their awareness of environmental issue.

Strenghts of this research are: show how use of persuasive technologies can have collective benefits and demonstrate their informational power.

Theoretical Framework

Real and Computer Mediated Persuasion

There are many definitions of persuasion in social psychology, in their review Roloff and Miller (1980) tried to offer a clear definition of the expression 'to be persuaded'. The first generally accepted important distinction concerns coercion; persuasion can be indirectly coercive or coercion may be anticipated by a persuasive communication. The second assumption highlighted by the authors is that persuasion is often built on a symbolic negotiation. Some earlier authors (Woolbert, 1917; Rowell, 1932) argued that there is a distinction between persuasive communication and an oriented conviction communication, associating the former with the emotions and irrational thoughts of the receiver and the latter with rational and logical aspects of reasoning. More recent studies have confirmed that persuasive communication is based on both types of reasoning, logical and irrational or emotional, which can follow different processing paths or join in a unimodal process (Kruglanski, Thompson, & Spiegel, 1999).

Nilsen (1974) identified the goal of persuasion as inducing beliefs or actions in other people, giving the term an entirely negative slant, based on the assumption that persuaders would care only about their own interests. More recently Cavazza (2005, p. 131) suggested the following definition for persuasion: “the communication process in which a source presents arguments and facts, reasoning and conclusions directed to induce a change in the receiver”, in other words, a process that culminates in an effective and measurable change of an attitude, a behaviour or a belief in the receiver, i.e. the target of the persuasive communication.

In 1981 Petty, Cacioppo and Goldman carried out an experiment to test the hypothesis that the personal motivation is an important determinant of attitudinal change. They manipulated level of personal involvement and the subjective relevance of persuasive arguments and confirmed their hypothesis.

The concept of persuasive technology links particularly well with the concept of indirect pressure exerted by an active source of influence; this indirect pressure takes the form of messages that evoke the advantages and disadvantages of a specific action (Mucchi Faina, 1996) and can be contrasted with varying levels of direct pressure on a target to behave in a certain way.

According to Fogg (1997), persuasion should not be construed as manipulation, but as an act or a communication aimed at encouraging a change in attitudes or behaviours; a technology can be defined persuasive when it is designed with a persuasive intent and in this sense the eventual effect should be considered planned rather than adventitious.

The Social Relevance of Environmental Issue

Environmental protection is a subject of great social interest at a macro-social level: In 1987 the World Commission on Environment and Development (WCED) included on its list of topics of interest the concept of sustainable development, thus bringing it to public attention. The Earth Summit held in 2002 in Johannesburg further developed the topic by recognising that there are ecological, economic and socio-cultural dimensions to sustainable development.

Every year there is an International Climate Conference involving about 160 nations at which initiatives to protect the planet and slow down anthropogenic deterioration as much as possible are shared. This led to the 2015 Paris Agreement on measures to minimise climate change.

From a sociological point of view there are different ways of approaching the issue of the environment, for example Kohl (2008) declared that environmental sustainability can only be brought about through social participation and interdisciplinary communication, since environmental problems are not confined to one sector and cannot be addressed or resolved by a single type of competence or by a single country. Järvelä (2008) extended this line of argument, suggesting that the development of a society should comply with the principles of social sustainability (Järvelä, 2008).

The concepts of environmental care and sustainable lifestyle can be dealt with at three levels of social intervention: macro, meso and micro. The macro-level involves joint initiatives by several countries in different parts of the world, but says little about how what changes individuals should make to their daily lives and behaviours to protect the planet. There have been numerous studies in social and environmental psychology highlighting this discrepancy between declared attitudes and the behaviour of individuals (Tversky, 1969). Often individuals interpret their behaviour as being useless or of little importance compared with the size or gravity of an issue and so they think that the efforts of individuals will have little impact on the environment (Maréchal, 2010). In addition to the impact of actions awareness, other factors that determine the creation of new behaviours are the individual's perception of his or her control over the action to be performed (Ajzen, 1991) and the perceived ease of incorporating a new behaviour into one's routine, i.e. making it a habit habits (Ajzen, Brown, & Carvajal, 2004).

Stern defined behaviours that have a positive impact on the environment (pro-environmental behaviours) as behaviours performed with the intention of changing the environment in a positive way, but also highlighted a rather frequent problem in this area: there is often a mismatch between good intentions towards the environment and the actual impact on the environment (Stern, 2000). There has also been an increase in concern about the condition of the environment, but this is increasingly associated with poor actual knowledge (Gifford, 2007).

Augmented Reality

Augmented reality (AR) consists of the union in real time of virtual objects in three dimensions with the actual surrounding environment; in more technical terms it represents an evolution of virtual environments (VEs) in which a user can interact with virtual elements in 3D in a completely artificial way. What makes AR novel and different from conventional VEs

is that this interaction occurs in the real environment: virtual objects are superimposed on the real ones and integrated into the context of the real environment (Azuma, 1997).

The relevance of this technology is that the integration of digital elements into a real-world context can provide the user with useful inputs during the interaction with the environment; digital elements they are useful for carrying out specific activities or tasks and the digital elements can also represent additional information content.

In 1997 Azuma defined AR as a technology characterised by three elements: the union of virtual and real, interactivity and representations in three dimensions (Azuma, 1997). Subsequently Craig deepened and widened this description by adding other elements to the definition of AR (Craig, 2013):

- The real or physical world is expanded by the presence of digital information superimposed on the information already present.
- The information is displayed in conjunction with the user's perception of the real world.
- The digital information content that is present depends on the location and on the user's perspective on the real world.
- The experience provided by the AR is interactive on several levels: the user can change the digital information, create new information or change his or her perspective and interact with the same information from a different point of view.

AR applications work by determining the real world position and orientation of the rendering device (its *pose*) with respect to the surrounding location, this is often referred to as SLAM (simultaneous localisation and mapping). Determining pose within an environmental context often involves a combination of sensor-based (using accelerometers, gyroscope, etc.) and vision-based (using camera, depth sensors and artificial intelligence to recognise and locate either visual fiducial markers or map and learn objects and the surrounding area) techniques. Some ARs also exploit Bluetooth markers, wi-fi signal triangulation and global position satellite (GPS) data to locate the rendering device in a context.

A fiducial marker-based approach offers a robust means of superimposing information and virtual objects on top of real objects, but it requires the placing visual markers (logos, Quick Response Codes, etc.) beforehand, which maybe an undesirable visual intrusion within a domestic setting.

An object- or area-learning approach is less robust but requires no prior interference with the real location. In our pilot studies we used area learning facilitated by devices supporting Google's 'Project Tango' application interface (API).

Below are examples of AR with and without a fiducial marker (Figures 1 and 2).

[Figures 1 and 2 about here please]

Several authors have already shown an interest in AR in various socially relevant contexts, for example the development of applications to support learning. It has been argued that through students' collaboration and sharing of real space augmented with information and digital elements it is possible to improve a learning environment (Price & Rogers, 2004). In particular, environments enriched with technologies that use AR can inspire more and more students, whereas more traditional technologies such as a computer or a tablet actually reduce users' opportunities to interact with others and with the environment (Price & Rogers, 2004). Other researchers have examined the merits of AR as a method of supporting the sort of experiential learning that can occur as a result of a direct experience in reality (Huang, Chen, & Chou, 2016).

It is believed that in tourism AR can take the form of an online VE in which tourists can learn about new places and contribute to the tourist experience by providing additional information on specific sites (Jung, Chung, & Leue, 2015). Some tourism AR applications have already been developed, for example Historical Oslo offers users a real-time comparison of the places they are visiting with the historical reconstructions of the same places in AR, and additional content adds to the tourist experience (Chen, 2014).

A recent work by Craig (2013) described developments in AR in fields as diverse as medicine, advertising, arts and entertainment.

With regard to the use of AR in relation to environmental issues and sustainable lifestyle, a recent strand of research concerns ways of strengthening of people's awareness of and affection for the natural environment. Other scholars have evaluated the power of a VR game to improve recycling habits and reduce pollution (Carmen Juan, Furiò, Alem, Ashworth, & Cano, 2011). In all these cases an important aspect of the applications has been that they are fun to use, because they were tested in samples of children and students; this may have created a sort of technology acceptance bias. The literature contains more studies addressing the issue of the relationship between environmental protection and technology, especially mobile and pervasive technology; for example Martos and colleagues (2016)

suggested that mobile devices could play a role in keeping the level of pollution in cities under control.

The Pilot Study

The primary objective of the research planned and conducted in Salford was to develop and test an AR-based application for the mobile device Samsung Tango. The application was intended to stimulate a change in users' attitude and behaviour and increase their households' environmental awareness. Thus it was hoped the application would deliver a twofold benefit: individual users would benefit financially from changes to the way they manage their house and their community should benefit as well, since pro-environmental behaviour by individuals has indirect benefits for society.

A multidisciplinary research team developed the application for the mobile device Tango and assessed its usability and effectiveness. We tried to take into account the factors highlighted by Craig as conducive to successful use of AR (Craig, 2013). Craig stated that the first priority should be that the tool is aesthetically and functionally pleasing, for example it should be fun to use and also provide timely feedback. The application should obviously be able to perform the function for which it was designed and be simple to use or provide appropriate instructions for users.

It is also important that the application is suitable for conditions in the target use environment, for instance if the device is to be used outdoors it must be capable of providing a clear display under various natural light conditions. Craig also referred to the importance of an application providing additional value simply by virtue of being a technological novelty. Finally it is important that the device on which the application is implemented shows no errors during its use or that they are predictable and changeable, and it is possible to update the application.

The pilot study was designed with two main objectives in mind:

1. Evaluate the tool from an educational point of view, specifically how successful it is as a method of conveying meaningful information about pro-environmental behaviours.
2. Observe and assess whether the application developed for Tango promotes pro-environmental behaviours.

Eight volunteers were recruited during University classes; they were given detailed written information about the study and its objectives and provided written consent to participation.

The experimental part of the study was carried out in the Energy House, in the School of the Built Environment at the University of Salford. This was the perfect setting, because we were interested in behaviours inside the home. The Energy House is a real, English-style house, the only house in Europe that has been placed in an environmental chamber capable of producing different climatic and atmospheric conditions and the only such house in the world that is made of bricks. These features make it ideally suited to conducting experimental studies of new materials, systems and equipment for energy saving, but also of behavioural changes associated with the adoption of various energy efficiency measures in the House.

Study Design

The participants arrived at the Department in which the Energy House is located according to the agreed timetable; they were asked to fill out an anonymous screening questionnaire useful to identify their attitudes to environmental issues and technology and to certain behaviours and habits.

Later, one person at a time was accompanied to the Energy House to use the application implementing the AR; this activity lasted about 15 minutes.

Immediately after their experience in the House participants were interviewed to obtain information about their first impressions of the device used, their attitudes and opinions on the topics covered and the type of experience they had just undergone; finally they were asked if they had any suggestions for future improvements to the application or device.

The participants used the device inside the House, observing the seven scenarios. Each scenario represents a problem that is frequent in domestic life in Britain. The participants viewed a 3D animation accompanied by informative content shown on the device's display:

1) Flying coins were presented on the windows of the living room in AR, to represent the cost of having single-glazed windows; the following associated information was presented:
    - Single glazing: a single-glazed window does not provide effective insulation and the loss of heat through the glass means that more energy is consumed to maintain the desired temperature.
    - Double glazing: installing double glazing in all the windows in the average three-bedroom home would save about £150 a year on the heating bill and the double-glazed windows should last for 20 years or more.

2) There was an animation on the television screen, the device showed a video depicting the pollution from a power plant with the following information:
    - The use of the standby mode on many different appliances in a home is responsible approximately for 5-10% of a home's electricity consumption. In global terms it is responsible for 1% of global CO_2 emissions.
    - Turning off electrical devices will do more to reduce energy use than anything else. A decrease in electricity consumption means that less power is used, resulting in less pollution from the burning of fossil fuels.
3) In the kitchen of the House there was a washing machine, on which the participants saw a polar bear dancing or sad and depressed depending on which temperature option was selected:
    - Setting the temperature to 30°C instead 60°C corresponds to an energy saving of more than 60%; the energy savings from a reduction of only 3°C in the average wash temperature of people in Europe would be equivalent to eliminating the emissions produced by around 700,000 cars.
    - Even a 10ºC increase in wash temperature increases the environmental impact of doing laundry, because the most energy-consuming aspect of the process is heating the water.
4) Moving to the second floor of the House revealed a large carbon footprint on the stairs, intended to represent the environmental impact of CO_2 emissions and their relationship with choice of room temperature:
    - Increased use of non-renewable energy makes the planet warmer, the CO_2 emissions contribute to the greenhouse effect and increase a person's carbon footprint.
    - The ideal room temperature for the domestic home is 20°C; turning the thermostat down at least one degree in winter (and up in summer) for 8 hours a day can radically reduce one's carbon footprint and save at least 5-15% per year on energy bills.
5) In the bedroom an AR mountain of waste was placed on the bed and information comparing light-emitting diode (LED) light bulbs and traditional incandescent bulbs was given:

- Although LED bulbs are more expensive to buy, in the long term they will save energy and money and reduce pollution. The lifespan of an LED bulb is about 50,000 hours.
- The first incandescent light bulb was invented in 1879, and although extraordinary improvements have made since, they remain extremely inefficient; their lifespan is about 1,200 hours and so they need to be changed fairly frequently and there are strict rules about disposal.

6) Inside the bathroom the theme was water conservation, the digital element added was a wilted flower.
   - Having a shower takes between 5 and 12 minutes, using up to 60 litres. Reducing the excessive use of water can help wildlife in our rivers and oceans.
   - Taking a bath can use up to 100 litres. Given that the UK has less water available per person than most other European countries it is important to be aware of how much water is used by various tasks.
7) The last scenario appeared near the ceiling at the top of the stairs and showed animated people trembling with cold or feeling comfortable.
   - Insulation means more comfort and lower CO_2 emissions; if everyone in the UK installed 270mm of loft insulation the country would save over £500 million a year in energy consumption.
   - Heat rises, so without loft insulation a home will lose up to 25% of its heat, as a result the inhabitants will be colder and spend more on gas or electricity to achieve a comfortable room temperature. On average loft insulation remains effective for 40 years.

Results

We subjected the data obtained from the first screening questionnaire and from individual interviews to qualitative analysis. There are many different points that are worth noting.

The first point to emphasis is that there were cultural differences in awareness of environmental issues. Not all the participating students were of British nationality and those of other nationalities were used to different climate and household issues; some were fairly indifferent to the information provided. Clearly it is crucial to coordinate the different levels

of intervention: as different countries have shared the same intents and action plans for the reduction of environmental problems, it is inevitable that the succeeding interventions in the single territories must be diversified and also socio-cultural researches on this topic should be highly dependent on the native culture.

In some cases there was a discrepancy between the attitude towards technology declared in the initial questionnaire and the impressions recorded at the end of the experiment: an initially negative or sceptical attitude toward technology had turned into a positive opinion of the merits of using AR to increase individuals' awareness of environmental issues and stimulate a change in behaviour.

Analysis of the interview data revealed a general enthusiasm for the AR experience. Only one participant had previously used similar technology, so novelty definitely played a key role in participants' impressions. All respondents recognised the informational power of the application, they considered that the mode of transmission mad the information was useful, easier to remember and more immersive, compared with information transmitted via more traditional methods such as scientific texts or television. Participants also appreciated the wealth of facts and objective data. These provided information that most people do not know and may not be interested in learning about, because - according to our sample - people tend to view environmental issues as a global concern rather than as directly related to one's personal everyday life. Many of our participants reported that as a resulting of using the VR application they had learned that there are simple actions that can be performed in the home that will have a positive effect on the external environment. Although the experience and the instrument were generally appreciated, participants were also asked to express any doubts about the use of such a tool in daily life and to suggest changes or improvements for the future. Some expressed doubts about the convenience of the tool: they found uncomfortable holding the tablet and moving it to frame the digital elements on the screen and noted that sometimes one had little time to learn new information; others suggested that allowing users to explore the information conveyed by the device in more details would make the application more effective. When asked about everyday use in one's home participants suggested that it would be useful to have a similar application available on smartphones. One participant said that the tool and the application were still too simple to be implemented outside of a research context, but in this context it is important to note that the majority of participants were graduate students of Computer Science and therefore had moderately good knowledge of technology.

Some participants noted that the application had some persuasive characteristics, for example the information was detailed and specific; getting the amount of information to be assimilated right can make it easier for users pay attention to key environmental concerns. This latter feature, together with the peculiarities of AR, which makes it particularly engaging, mean that the tool is also suitable for children and would be a valuable teaching method.

It was clear even to the participants themselves that many people are not fully aware of environmental concerns, in particular the issue of pollution. Much of the information provided was new to participants, many of whom did not know the difference between single and double glazing or the difference in fuel consumption between an electronic device in stand-by mode and one that has been switched off. The most common pro-environment behaviour amongst our sample was recycling, the habit of turning off all the lights in the house and paying attention to water consumption were also cited. The main motivation given for such behaviour was saving money, some also mentioned the importance of their actions for the environment and for the care of the planet we share.

Finally the scenario with the polar bear was the best liked (see Figure 3): it was considered to combine a very vivid and appropriate image with useful information.

[Figure 3 about here please]

Only one participant mentioned the risks of dependence on technology, which is unfortunately already high amongst the younger generation because of daily use in the home.

The results from this small, non-representative sample showed that students make two linked assumptions about environmental issues and the benefits that the use of technology can provide. They admitted that they - and probably the majority of people - took a fairly detached perspective on environmental issues, which they still defined a global concern that was distant from their daily lives. They also found real advantages to the application, which stimulated awareness of environmental issues in a pleasant way and thought it might be useful in stimulating and supporting some of the behaviours necessary to protect the environment.

Conclusions

The choice of environmental issue was determined by certain theoretical considerations: the benefits to society from the personal use of an application may indeed be identified in the pro-social behaviour or in charitable actions or socio-cultural activities for

integration, but it has been preferable to choose a theme that was not overly sensitive in a psychosocial sense in order to exclude some purely individual variables such as for example altruistic personality traits, the ability to empathise, discomfort or personal well-being. The information presented in this environmental module was based on objective, universally recognised and shared data. Although there are cultural differences and differences dictated by the climate and social conditions in each country, there are, nevertheless, global initiatives underway to promote pro-environmental behaviours and attitudes at individual and community level.

The future development of this pilot project will include updating the application on the basis of the results obtained in these early tests, which were directed at assessing the application and implementation device from a technical and theoretical point of view. The updates will make the application informationally richer, enabling users to find out more about a particular issue and inserting links to data sources to provide greater credibility. According to a recent study (Fantinelli & Cortini, 2018) informational power is a positive predictor of use of AR applications. The extant literature also suggests that use is predicted by the fun factor, but in this case we can hypothesise further analysis to better assess the user's perception: does an application keep its persuasive power even if the usage probability is mainly affected by the perceived fun? Do people who use the applications because it is fun to use still derive information and motivation from doing so?

Another variable that influences pro-environmental behaviour is sense of belonging; Lalli (1992) demonstrated that people who identified with the place where they live were more sensitive to environmental issues than those who felt no sense of belonging.

This pilot study is original because it considers perceptions of both individual and collective benefits of persuasive technologies. The decision to carry out a pilot study was determined by two factors: the use of AR as technology and the fact that there are no previous studies using this technology to implement persuasive principles in order to simulate a shift to a more sustainable lifestyle. These two factors led the research team to carry out this pilot study. We now intend to replicate the study with a large sample to provide a first comprehensive evaluation of the method and the adopted technology.

Persuasive technologies are typically designed respecting ethical parameters, but they may have consequences that pose a threat to communities and so there should be further social and psychological investigation into their use. For example, it would be useful to assess users' perceptions of the utility of the application or their endorsement of the altruistic principle that underlies it. Finally according to the Fogg model (2003) persuasive

technologies may become socially, psychologically or technically obsolete, especially if advances in the field of human-computer interfaces and usability continue. Hence another challenge for the future concerns the updating of the design of persuasive technologies.

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Figure 1. Example of recognition-based AR: a Topps baseball figurine. [Source: Ney York Times]

Figure 21. Example of superimposition AR for a medical-educational use. [Source: AugmentWorks]

Figure 2. Example visualization of the application which shows the polar bear in AR. [Source: Ian Drumm, Salford University]