Applications Virtually Augmenting Real Experiences for Behavioral Change

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Abstract. Design for Sustainability is a research area based on a multidisciplinary approach, which has become increasingly important in recent years. Among the several approaches to Design for Sustainability emerged in the past decades, great attention is paid to the "Design for sustainable behavior" approach, used to design products that can impact on users' behaviors, through embedded smart technologies, e.g., Internet of Things (IoT). In fact, IoT systems are able to "dialogue" with the users, supporting the identification of any misbehavior, and suggesting more sustainable ones. The authors identified the opportunity to design and develop AR interactive applications aiming to generate awareness about the impact of humans on Earth, make people reason about how they can directly contribute to limit the expansion of this problem and induce their behavioral change. The applications are meant to engage users in an active process of exploring and discovering informative contents and to foster them to elaborate a personal and critical vision and change their bad habits. Specifically, this paper presents two case studies about the design and development of Augmented Reality applications and IoT products to be used for supporting users towards more conscious food consumption in their daily life, in order to reduce food waste.

Keywords: Design for Sustainable Behavior, Design for Behavioral Change, Augmented Reality, Food waste.
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1 INTRODUCTION

The increasing concerns for issues related to sustainability rise new research questions in the design domain aiming to limit the negative impact of human actions on the environment and on society. In particular, Design for Sustainability is a research area based on a multidisciplinary approach, which has become increasingly important in recent years. The main goal is to design and develop more eco-sustainable products and services as regards to production, reuse and recycling processes. Among the several strategies and approaches used to meet this important

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topic, the design discipline has been engaged with different aspects of sustainability subject and practice. More specifically, according to [4], several approaches to Design for Sustainability have emerged in the past decades. Among them, they highlighted the "Design for sustainable behavior" approach, which is based on the fact that the users' behaviors produce important environmental impacts [23].

The idea that a particular design affects the users' behavior is not new: Norman already discussed how products invite us to perform certain actions on and through them, guiding and potentially changing our behavior [21]. However, more recently we started reasoning about the rebound effects that the users' attitude has on the main challenges we are facing on the global and local scales, including resources consumption, environmental damage, health and social issues. For this reason, designing products to support users' behavioral change is becoming one of the most popular trends in the current design research. Provided that, several design experiences based on the use of advanced technologies, e.g., Internet of Things (IoT), Augmented Reality (AR) and Virtual Reality (VR), have been proposed and experimented. In fact, one of the key features of AR and VR applications is "Interactivity", which is the possibility for the user to actively interact with all the digital elements present in a virtual environment. In addition, interactivity is an important aspect in the domain of Design for Sustainable Behavior, because it allows us to "create a dialogue" with users, engaging them in the experience, supporting them in the identification and understanding of any misbehavior, suggesting more sustainable ones and eliciting pro-environmental and pro-social behaviors. Indeed, the behavioral change of a huge number of people is of fundamental importance, since only a collective change will bring to effective results.

On those bases, the authors identified the opportunity to design and develop AR interactive applications with the aim of generating awareness about the impact of their food consumption habits on Earth and induce more sustainable behaviors. In particular, the paper presents two case studies about the design and development of Augmented Reality applications and IoT products to be used for behavioral change. Specifically, the literature review in the reference research areas, and the research objectives will be presented. In addition, the paper discusses two case studies of AR applications developed for supporting users towards more conscious food consumption in their daily life, in order to reduce food waste.

2 RELATED WORKS

2.1 Design for Sustainable Behavior

Design for sustainability is part of the "sustainable development" [2], which has been defined in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [25]. Among the several strategies and approaches used to meet this important topic, the design discipline has been engaged with different aspects of sustainability subject and practice [4]. More specifically, according to [4], several approaches to Design for Sustainability have emerged in the past decades. Among them, they highlighted the "Design for Sustainable Behaviour" (DfSB) approach, which is based on the fact that the users' behaviours produce important environmental impacts [23]. DfSB aims at facilitating users' link "*between the information, their own behavior and the environmental and social impact*" because the difficulty to understand this process is what "*makes it difficult to motivate a change in the majority of users' behavior*".

On this basis, several approaches and models to influence behaviours and achieve behavioural changes focused on finding effective strategies to persuade have been developed. Persuasion can be defined as a non-coercive attempt to change attitudes and behaviours. Among them, [1] developed the DfSB model, that proposes a set of "design intervention strategies" which can be applied within design to inform, empower, provide feedback, and reward (with incentives and penalties) users. Moreover, other design strategies rely on "automatic" interventions, such as design solutions combined with advanced technology to persuade or control users' behaviours. However, a change in the user actions is not guaranteed yet. This because *habits* play a

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fundamental role as mediators of behavioural change [1]. Then, Bhamra [1, 19] explains that "*to encourage consumers to break old habits, two factors are suggested: repetition and reinforcemen*t".

2.2 ICT Technologies and Design for Sustainable Behavior

The state-of-the-art technology in the ICT domain can provide a huge boost to this process, enabling the users to interact with several kinds of digital contents in a stimulating experience. Indeed, ICT technologies can be used in the design of interactive systems, products and applications to allow a "dialogue" with the users, and to support them in the identification and understanding of any erroneous behaviour, and to suggest more sustainable ones. In those cases, the design of the user-system interaction represents one important aspect to take into account in the overall design process.

Furthermore, the possibility to use interactive technologies to monitor the users' behaviour and push them to start new actions, can be particularly effective in fostering durable behavioural changes and generate new habits. Indeed, a well-designed interaction can be particularly effective for two reasons. First, it engages the users' body, an aspect that is considered fundamental for improving our understanding and learning process according to the well-known psychological theory of embodied cognition [22]. This theory suggests that cognition is heavily grounded on sensory-motor experiences, meaning that better learning is achieved when the body is involved in the process, as compared to when the experience consists in a mere observation or listening. Second, being actively engaged in the interactive process, instead of being the passive recipients of inputs and notions, it allows the users to catch the deep meaning of the subject-to-be-learnt, to develop logical and semantic links with related topics, and to elaborate a personal and critic vision.

For all these reasons, AR and VR interactive applications are becoming more and more appreciated and effective, involving people through different senses and calling them to action. Specifically, as suggested by [5], three design principles should be used for the design of educational AR experiences. Those are *Enable and then challenge*, *Drive by gamified story* and *See the unseen*. Dunleavy's design principles [5] are closely connected to Malone's key elements of intrinsically motivating instruction [20]. Specifically, what Malone [20] considered as relevant was intrinsic motivation, in opposition to externally administered reinforcement, which seemed to be counterproductive in educational contexts. The elements that according to his theory make environments intrinsically motivating are *Challenge*, *Fantasy* and *Curiosity*.

2.3 AR and VR Applications to Support Sustainable Behavior

In the context of this research area, several applications and smart objects have been developed with the aim of making people think about the impact of humans on Earth. For instance, the "After Ice" [10] mobile application uses AR to simulate the effects of climate change around the world. The app simulates your location in various future scenarios of global ice melt and sea level rise. Also, on the basis of the "Human Footprint" exhibition [17], the eoVision company developed a book named "OneEarth", consisting of a collection of 119 satellite images used to show the status of the Earth's environment though an AR application. Similarly, NASA created different applications based on pictures from its satellites and missions. Among them, a virtual gallery named "Images of Change" [6] features images of different locations on planet Earth, showing changes over time periods.

Among the several applications related to environmental sustainability and the food waste phenomenon, the authors identified two main areas. Some applications aim at influencing the food purchasing and food consumption phases, while others aim at preventing the surplus food waste problem. The first typology of applications offers the user the more sustainable choice between different solutions proposed in the supermarket. For instance, "Giki Badges" [7] underlines the true impact of products and helps the user to select eco-friendly brands while "NoWaste" [15] and "Foodfully" [12] educate the thoughtful consumption of food before the expiration date.

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The second category of applications instead is more focused on the food sharing to solve the surplus food waste problem. In this context “Olio” [9] is an application that allows individuals or companies such as food retailers, restaurants, corporate canteens, to donate unconsumed food. Similarly, other applications as “Karma” [8] and “Too Good to Go” [11], indicate where to find excess stock at restaurants, grocery stores, wholesalers and farms, showing exactly what items are available: in this case, the user can reserve and pick up the food getting a price discount.

The applications considered present interesting implications concerning the sustainability topic, but they are mainly dedicated to “active” users, already informed about eco-friendly solutions. In this case, the user is so proactive in his/her sustainable behavior that he/she willingly accepts to buy already processed, or almost expired, food. In this context, another application designed for active users is “Food Rescue Hero” [14], used by volunteers to transfer fresh food surpluses from local businesses to social service agencies.

The experimental case studies discussed in the paper, instead, present an educational purpose aiming at informing and engaging people that have little or no knowledge about the virtuous behaviours. Moreover, the presented projects differ from the existing applications for the use of an effective graphical representation of the data, to explain in detail the food characteristics at the time of purchasing. Indeed, some of those feature badges indicate the category and rating of food, while others only allow us to insert bought groceries, becoming a sort of electronic shopping list.

Lastly, the authors underlined a lack of interactive applications for children on the market related to the food waste topic. In fact, sustainable behaviours are mainly promoted through storytelling by applications as “Awsome Eats” [18], yet not involving kids to accomplish real environmental choices. Therefore, it is interesting to present a more engaging solution to stimulate a responsible attitude in kids towards the environment, in everyday life.

3 EXPERIMENTAL CASE STUDIES

On the basis of the literature review, the authors identified the opportunity to design and develop AR interactive applications aiming to generate awareness about the impact of humans on Earth, make people reason about how they can directly contribute to limit the expansion of this problem and induce their behavioural change. The applications are meant to engage users in an active process of exploring and discovering informative contents and to foster them to elaborate a personal and critical vision and change their bad habits. In particular, two case studies addressing the “food waste” phenomenon, which is one important erroneous behaviour related to environmental sustainability and to users' daily habits, will be presented.

According to the FAO (Food and Agriculture Organization of the United Nations), in 2011 the annual global food waste was estimated to be about 1.3 billion tons, equivalent to about a third of the total food production intended for human consumption. According to the USDA [3], in the United States a total of 31% of the food intended for human consumption is wasted each year, primarily in the home and in restaurants, and in Europe the food waste phenomenon is comparable. Specifically, in Europe, the amount of food wasted by consumers is noticeably higher than the food loss during the production and distribution phases. The effects of this phenomenon consist of waste of resources like water, land, energy, labour and money, and also of the production of gas emissions, contributing to the global warming and climate change.

Organizations and countries have implemented instruments to face this problem. In 2015, the European Union created a list of Sustainable Development Goals, including the goal of halving per capita the consumers’ food waste by 2030. Other examples are the awareness campaigns, such as the "International Day of Awareness of Food Loss and Waste" [13], and the SAVE FOOD project [16]. Also, some organizations (profit and non-profit) provide food aid by collecting food that would otherwise be thrown away and distribute it to poor people. Moreover, other initiatives are aimed at the reduction, recuperation and recycling of food products that can no longer be sold but are still edible. In spite of these and many other attempts, the amount of consumer food waste is constantly increasing.

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If we focus on food waste at home in developed countries [24], the phenomenon is primarily related to the over-buying of food, often induced by supermarkets' special offers, to the preparation of over-generous portions of food (at home and also in restaurants), to fresh food not being preserved appropriately and, more in general, to the low cost of food compared to disposable income.

3.1 EGGup Case Study

The first case study consists of a physical object connected to an interactive AR application, named "EGGup" which aims to raise people, including children, awareness about the impact of food waste on the environment, and to make them reason about how they can personally contribute to limit the expansion of this problem. The application uses chicken eggs as main communication element. Chicken egg has been selected because it is one of the main wasted food. The main reasons for that are the poor value attributed to chicken eggs, the fact that it is often cheaper to buy eggs in large package, also if users don't need such a big quantity, and that users don't pay attention to the expiration date. Despite this poor perceived value, eggs production involves a big consumption of water (200 litres for each egg), and a waste of resources like land, energy, farmers' work and money, and also gas emissions, contributing to global warming and climate change. Moreover, chicken egg has a very important symbolic meaning, since it is used in several cultures as symbol of life, of birth and regeneration, and even of wholeness. Given that, the design solution aims at informing the user about the eggs expiration date and at inducing him/her to consume the eggs before they expire.

EGGup is a system consisting of a Smart Egg Tray, integrating sensors and actuators, which is linked to an interactive App for monitoring eggs consumption, and for suggesting eggs usage and showing waste statistics to the users. The EGGup system has been designed according to the "design intervention strategies" proposed by [1]. In particular, Table 1 presents the used "design intervention strategies" and the corresponding design solutions used in the EGGup system.

Design Intervention Strategies	*Aims*	*Design Solutions*
Eco-Information	To make consumables visible and understandable.	The EGGup Parent's application gives information about the quantity and quality of eggs in the fridge, and statistics about eggs' consumption and waste.
Eco-feedback	To inform users about what they are doing and to facilitate consumers to make environmentally responsible decisions.	In the Smart Egg Tray and the Parent's application the eggs status is associated with a colour, and the user can understand which egg is edible (yellow colour), close to the expiration date (red colour), or already expired (grey colour).
Eco-spur	To inspire users to explore more sustainable usage by providing rewordings to good behaviour.	In the Children's application, an Augmented Reality educational game is used to make children learn more about food wasting and give them positive feedbacks through rewards and points.
Eco-technical intervention	To persuade or control user behaviour by design combined with advanced technology.	Technologies embedded in the components of the EGGup system are interconnected to support users in improving their food waste habits and increasing the awareness about "food waste" issue in children.

Table 1: Design intervention strategies and design solutions of the EGGup system.

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The Smart Egg Tray is designed to be placed in the middle shelf of the fridge. The tray includes a set of egg holes, each having touch sensors and LED lights in order to enhance the value of the eggs and give immediate feedback and information about the egg quality and expiration date. The tray is also equipped with a Bluetooth module to connect and send information to the EGGup App.

An important unit of the tray is the LED light, which is placed close to the bottom of each egg spot, to light it up directly. Another important feature of the Smart Tray regards the presence of touch sensors installed under the eggs spots and used to control each egg independently. The position of the touch sensors is studied so as to recognize the eggs even if they are placed inside the carton. Each LED light is well visible from outside thanks to the transparency of the case. Indeed, the external case is made by 3D printed Polylactic Acid (PLA), which is a polymer made from renewable resources with many suitable characteristics for this product. In particular, it does not release toxic fumes when oxygenated and can be safely used for any food packaging.

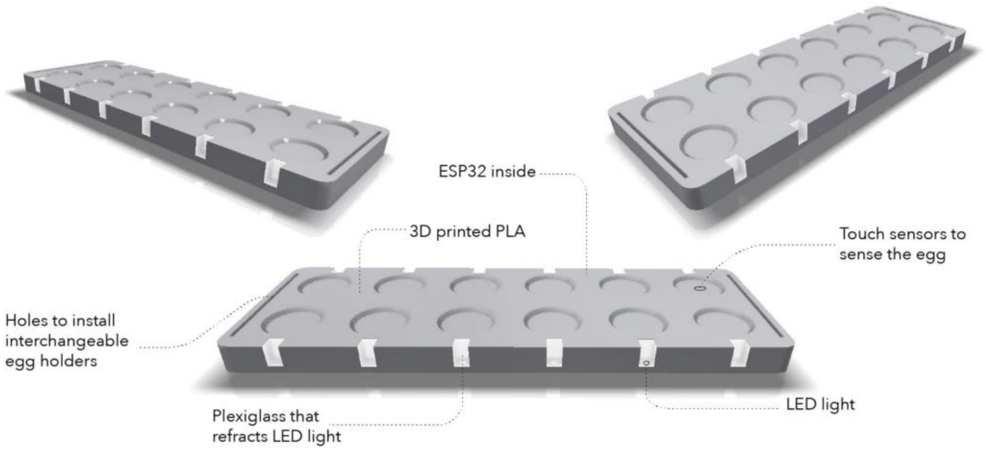

Figure 1: Components of the Smart Egg Tray.

The design process of the Smart Egg Tray has been based on the analysis of the dimensions of the eggs. The eggs can be classified as extra-large, large and small. The average dimension of an egg is 40-42mm by 53-59mm. Also, the analysis of eggs' cartons demonstrated that their average dimensions are 305mm by 105mm. Moreover, usually each egg spot has a maximum diameter of 45mm. So, on those bases, it has been decided to design an egg tray able to accommodate both eggs' cartons and single eggs, according to the users' preferences.

The designed Tray is usable with any egg carton. The groove perfectly fits any type of egg carton dimension and size: medium, large and extra-large cartons containing six, ten or twelve eggs each. Nonetheless, placing the egg carton on the smart tray can be a quick option. Some accessories have been designed to safely store the eggs one by one. Specifically, the egg tray presents holes to install interchangeable egg holders on it.

Indeed, the Smart Egg Tray can also be customized according to the users' preferences, by selecting a specific eggs holder, which can be installed onto the Tray by means of dedicated holes. Many different solutions and shapes have been explored to make the accessories perfectly adaptable to any customer's need (see Figure 2).

The EGGup App consists of two modules. The first one has been designed for parents to manage and control the whole system: it is connected to the Smart Egg Tray and to the children's App.

The parent's App is organized in three main areas, as shown in Figure 3:

– The *Profile area*, to access the personal account, see the statistics, manage the notifications and receive support in any needed situation.

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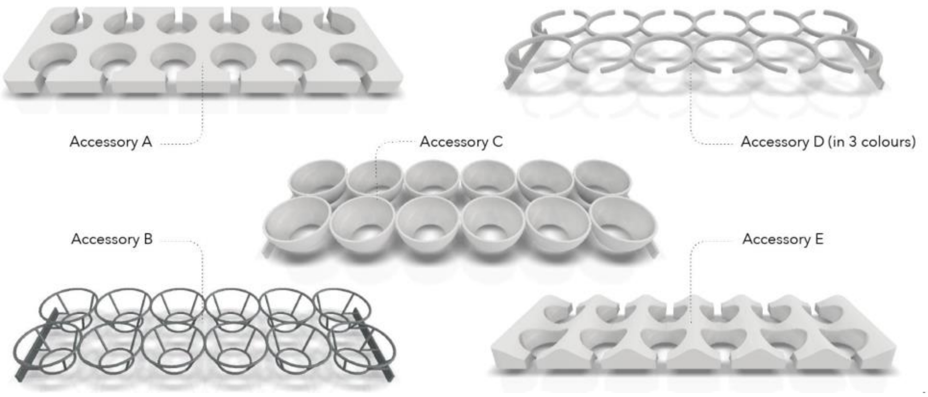

Figure 2: Models of Smart Egg Trays.

– The *MyEggs area*, to check the eggs lifetime. Indeed, the status of the eggs is clearly associated with a color, and the user can understand at a glance which one is edible, which one is close to the expiration date or already expired. This part of the application has been developed according the "*repetition*" strategy [1, 19 to help users in forming new habits about eggs consumption.
– An *area connecting with the children's application*. Here, parents can check children's statistics, set their goals and monitor their learning.

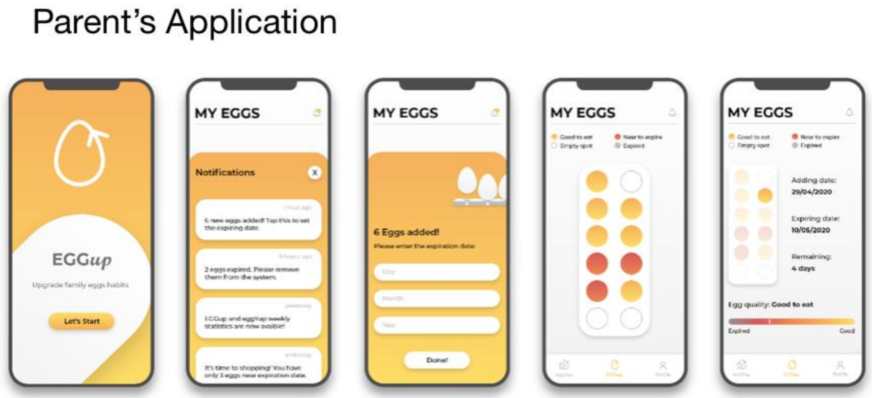

Figure 3: User Interface of the Parent's App.

The second module of the App has been designed for children, to improve their awareness about the impact of their habits on food waste through an "edutainment" approach, which combines entertainment and educational contents. The entertainment part consists of AR search of an Easter Egg hidden in the environment. When the kid finds the hidden Easter Egg, educational contents about the food waste problem in form of videos with fairy tales and legends can be enjoyed. The Children's App is organized in four main areas, as shown in Figure 4:
– *Home*, in which it is always possible to check the score and decide to gain extra points executing some proposed activities.
– *Achievements area*, which provides an overview of the completed and locked game levels.
– *Check Eggs memory game*, where the children are asked to check the eggs present on the Smart Egg Tray inside the fridge and associate each of them with the correct color code proposed by the application. In this way, the children can help monitoring the eggs status.

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–*Finding eggs game*, based on the Augmented Reality Easter Eggs search, where children have to find virtual eggs that are hidden somewhere in the house (see Figure 4). The game is used as a positive "*reinforcement*" [1, 19] for children, motivate them in frequently using the application.

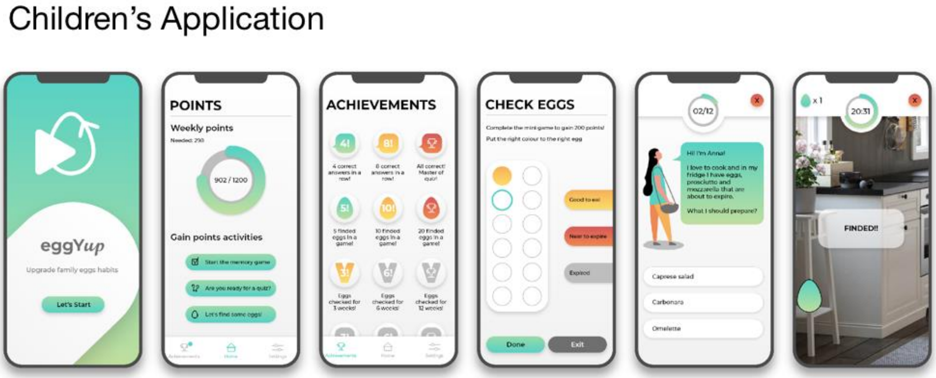

Figure 4: User interface of the Children's App.

For what concerns the User Experience of the AR Findings eggs game, children are guided in each step thanks to specific interfaces. Before starting the game, an Instructions page gives information about the tasks that the children have to accomplish during the treasure hunt, and on the points related to the different eggs they can find. In particular, finding a normal egg earns 50 points, while finding the gold egg duplicates the total score. When the child starts the Finding egg treasure hunt, a Unity script starts updating a timer, located on the application interface. The kid has 30 minutes to find the markers hidden around the house. Whenever he/she finds a marker, he/she can scan it using the camera of his/her device. Thus, the 3D model of the related egg appears rotating on itself. When the child clicks on it, some animations of the egg decoration cage are visualized, and the egg opens into four pieces, revealing some coins hidden inside. The gained points and the counter, showing the number of eggs that the child has already found, are displayed at the top of the App interface (see Fig. 5). At the end of the game, the App shows a summary page showing the gained points and the final score.

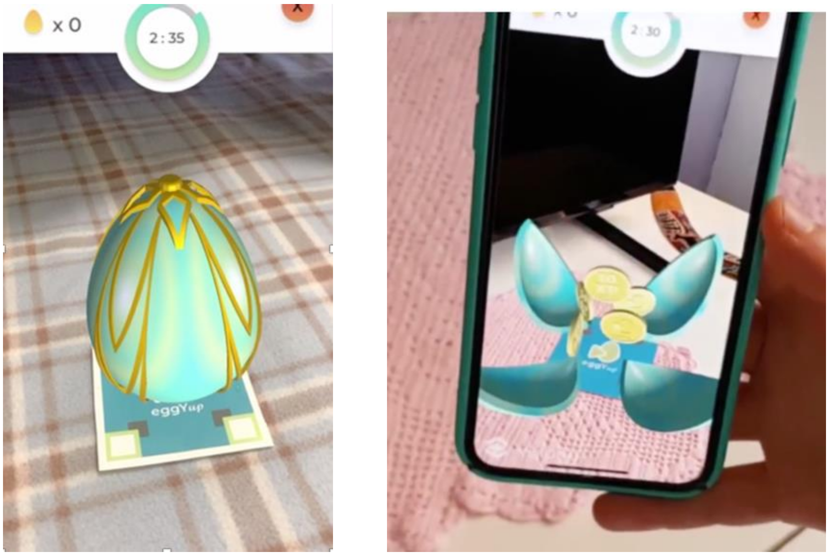

Figure 5: Two Screenshots of the Augmented Reality Finding Eggs game.

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A prototype of the EGGup system has been developed, including both the Smart Egg Tray and the Apps.

Concerning the Smart Egg Tray, the external case and the accessories have been manufactured by using Additive Manufacturing techniques. Furthermore, an ESP32 development board (DOIT ESP32 DEVKIT V1) and several components have been integrated into the shell (Fig. 6). Specifically, six Aluminum pads for ESP32 Touch pins have been used to sense the eggs. These sensors have been selected because of their high quality and low price. The touch pins have been connected to the ESP32 development board to send inputs to the application and also to control the six LED lights (RGB LEDS SK6812). An LED light has been associated with each touch pin. The board, the LED lights and the touch pins have been fixed in the proper position inside the tray shell.

The ESP32 board creates a TCP server to establish a WIFI connection with the parent's App (client). A circular buffer allows us to store 20 measurements of the touch pins. The average measurements taken by touch pins with and without the eggs have been initially compared to define a threshold. Then, when an egg is placed on the Smart Egg Tray, the corresponding touch pin registers a new measurement. If the measured value is higher than the threshold, the LED light related to the specific touch pin is turned on, and a message is sent to the parent's App. The message consists of the word «added» and the numbers of the triggered positions. It is possible to add multiple eggs at the same time and directly display them in the App. When an egg is removed and the value is lower than the threshold, the LED turns off and the ESP32 board sends to the application a message made of the word «removed» and the position of the removed egg.

When the user associates an egg with the corresponding status (good to eat, near to the expiration date or already expire), a string is sent to the ESP32 board, and the corresponding LED is turned on with the corresponding color.

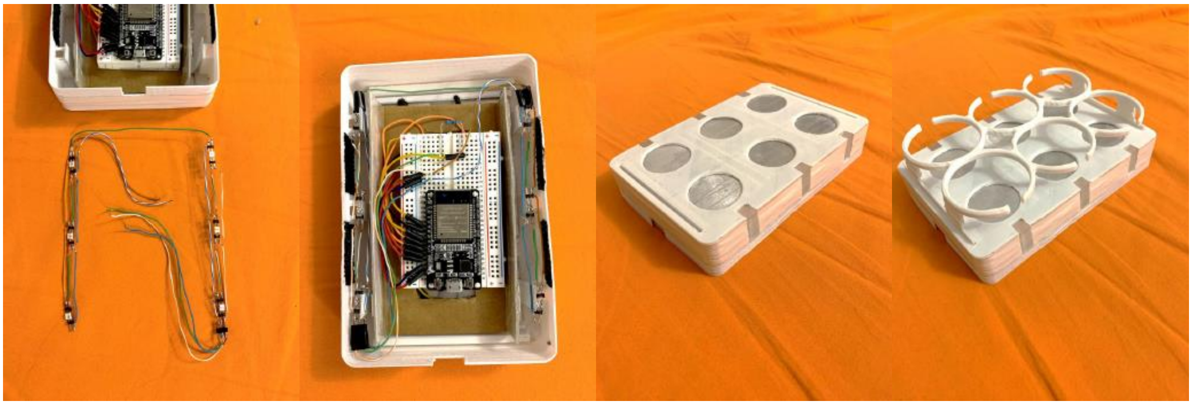

Figure 6: Smart Egg Tray physical prototype: shell and electronic components.

Unity3D (https://unity.com/) and Vuforia (https://developer.vuforia.com/) software tools have been used to develop the prototype of the two AR applications. Specifically, the virtual representation and simulation of the Easter Eggs have been developed in Unity3D, and the Vuforia software has been used for the development of the AR visualization of the contents.

The children's application features two different kinds of markers that allow users to visualize in AR two different types of eggs. Indeed, the children can find seven normal eggs (light-blue marker) and just one gold egg (orange marker) inside the environment.

Several scenes, animations controlled by an event system and scripts have been implemented in Unity and used to display various digital contents. In particular, for what concerns the parent's App, an egg-controller script updates the graphical visualization of each egg placed on a touch pin

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according to its status. Also, it has been implemented an algorithm that computes the quality of the egg based on the initial date inserted by the user. Also in this case, the App updates the egg visualization accordingly.

3.2 FOODDY Case Study

The second case study is focused on improving the users' awareness about the effects that their food consumption habits produce on the environment. The proposal consists of an AR interactive App, named "FOODDY", that provides truthful information and data about the environmental impact of food, with the aim to provide an educational mean to raise consciousness and persuade people to adopt proper environmental behaviours.

The FOODDY application is meant to be used during the grocery shopping at the supermarket. Here, the users can better understand their level of care for sustainability, avoid overbuying goods that are not necessary and be more aware of their purchasing choices. During shopping, the user can scan the product label and visualize information about the product sustainability characteristics, related to the carbon footprint, land use, water consumption, packaging and distribution. These items of information are not always easily accessible. However, they are of great importance to identify the most sustainable products, for example by comparing the total greenhouse gas emission and water consumption over the entire life cycle of the product.

The FOODDY application has been designed according to the "design intervention strategies" proposed by [1]. Specifically, Table 2 presents the used "design intervention strategies" and the corresponding design solutions used in the FOODDY application.

Design Intervention Strategies	*Aims*	*Design Solutions*
Eco-Information	To make consumables visible and understandable.	The FOODDY application gives information about products sustainability characteristics.
Eco-feedback	To inform users about what they are doing and to facilitate consumers to make environmentally responsible decisions.	The FOODDY application gives information about the users' current levels of sustainability given by their purchasing choices.
Eco-spur	To inspire users to explore more sustainable usage through providing rewordings to good behaviour.	In the FOODDY application, a virtual plant, showed by using the Augmented Reality technology, is used to represent the impact of users' actions. The virtual plant grows when users behave correctly, while it withers in the opposite case.

Table 2: Design intervention strategies and design solutions of the FOODDY application.

Each time the user frames a product, contents about it are presented through 3D elements and animations in AR. This repetitive process should positively impact on users' behaviours, helping forming new habits [1, 19. The AR App also shows the users' current level of sustainability, given by their purchasing choices. The users' actions are represented by means of a virtual plant, which grows when they behave correctly, and which withers in the opposite case. The virtual plant is used as a "*reinforcement*" [1, 19 for users' good behaviors. The FOODDY App also allows the users to record the purchased products, providing information about their quantity and alerting them about their expiration dates (see Fig. 7).

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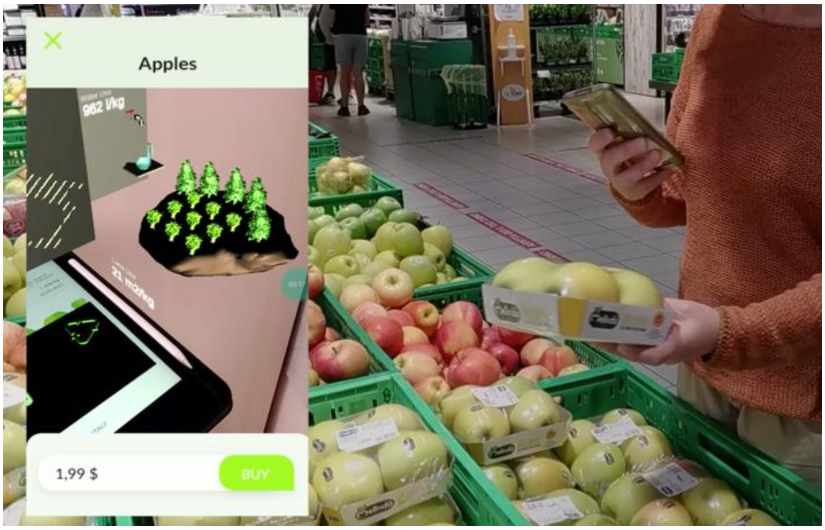


Figure 7: A screenshot of the FOODDY AR application.

Furthermore, a dedicated area of the App presents educational contents and tips that the users can adopt in their everyday life, for instance, for learning new methods for food preservation and storage. Specifically, the FOODDY App is divided in four main sections:

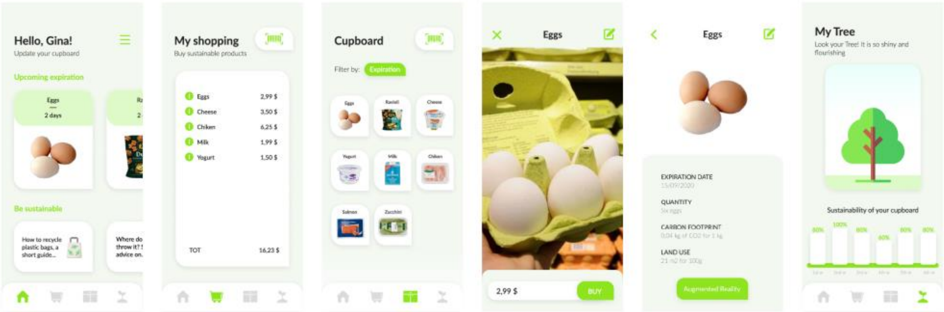
- *Home*, which presents reminders about products expiration dates. In this area some articles and videos are also presented as educational contents, to advise the user about correct sustainable behaviours.

- *MyShopping*, which is the part of the application most used at the grocery store. Indeed, in this page the user can activate the camera to scan the products labels and add the scanned items to a shopping list.

- *Cupboard* section, in which is possible to monitor the products already purchased. Here the user can visualize specific information about each product and monitor the expiration dates.

- *MyTree*, in which users can check his level of sustainability, based on the products he previously bought. As mentioned before, a tree illustration visually represents the good or bad behaviours.

In addition, the App uses colors that change according to the users' behaviour: bright green has been chosen to represent a correct trend concerning sustainability, and orange the opposite (see Fig. 8).



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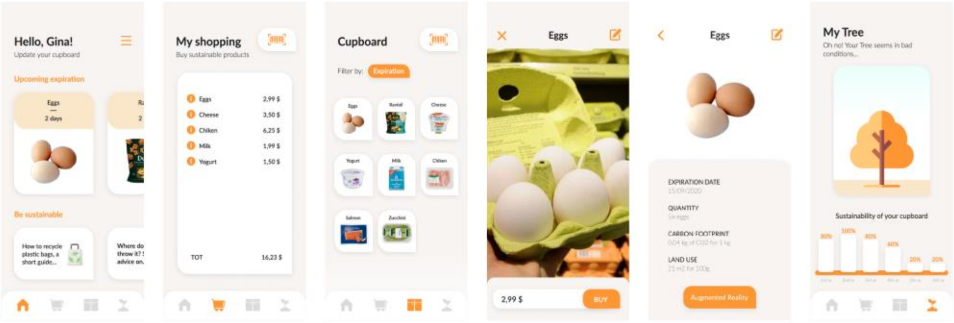

Figure 8: The App colors change according to the user's behaviour.

Also in this case, Unity 3D and the Vuforia tools have been used for the development of the prototype of the FOODDY AR App. More specifically, several scenes have been created by using Unity, each corresponding to a screen of the user interface. Regarding the AR contents, a different scene has been created to display the exact data. Three labels, related to three different products, apples, beef and eggs (see Fig. 9) have been used as markers for the development of the AR App. These three markers are used just as an example to represent the labels that the user can find on the product packaging, at the supermarket. In particular, these products typologies have been selected due to their different characteristics. Indeed, their sustainability levels appear to be really different. This aspect has been considered for the implementation of the prototype, in order to perform different data and visual elements.

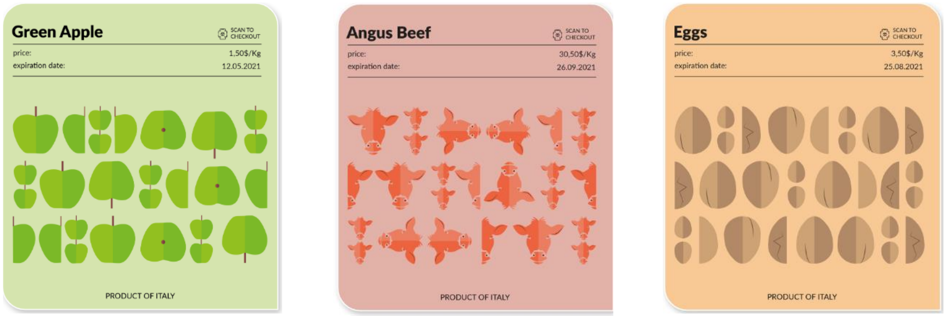

Figure 9: Markers of the Augmented Reality FOODDY application.

Regarding the User Experience at the grocery store, the user clicks on the user interface button at the top right of the *MyShopping* page, to scan the label of the product he/she wants to buy. When the user clicks on this button, the Unity AR scene is loaded, and the camera of his/her device is automatically activated. By scanning one of the markers, the corresponding digital contents appear.

Each marker is connected to various three-dimensional panels and interface elements that indicate the name of the product and the expiration date, its carbon footprint and land use, water consumption, packaging of the product and its origin and distribution. These contents change according to the type of food and product information. As an example, if the product is a seasonal vegetable or fruit, i.e. apples, a further panel appears. Some data is also represented thanks to the use of 3D models (see Fig. 10).

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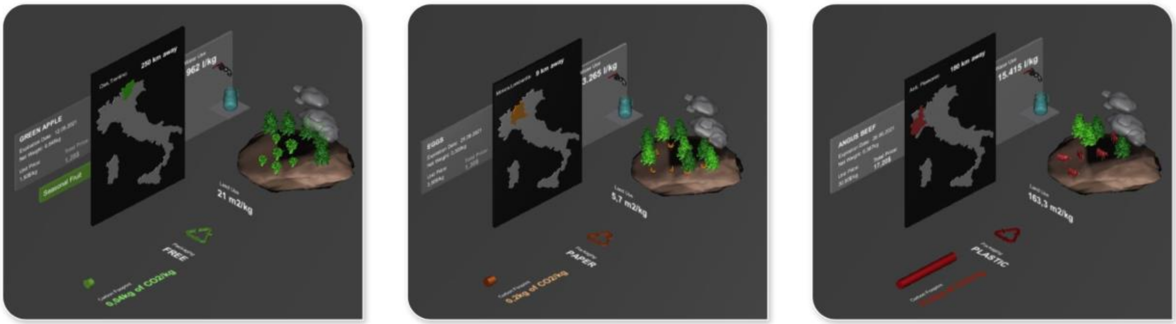

Figure 10: Augmented Reality contents, related to green apple, eggs and beef.

For instance, a 3D model of Italy shows the geographical origin of the food, while a loading bar shows the relative amount of CO2. Other 3D elements have been used to indicate the water use and the recycling packaging condition, to enhance the visual data representation. Moreover, the color of these 3D models varies according to the information shown, allowing the user to learn about the sustainability level of the product easily. In addition, depending on the scanned label, the 3D model of a land appears, indicating the land use, showing the cultivation or animal husbandry density, for apples, meat and eggs respectively.

Furthermore, when the user scans the product label, its price also appears automatically accompanied by an interface button.

By clicking on the interface button, the product is added to the *MyShopping* section, which displays the list of all scanned products. When the user purchases the products on the list, they are automatically moved to the *Cupboard* section, in which the user can reopen all the products details and access all the information already displayed in Augmented Reality. The product name and expiration date are marked priority information and they are used in the *Home* section to show the upcoming expirations.

The products on the *Cupboard* section have a direct influence on the *MyTree* section and on the App interface color. Indeed, specific scripts have been implemented in Unity to detect the product sustainability level and to calculate the user general sustainability index. Then, a threshold has been established to display the different trees illustrations in the *MyTree* area and to vary the App interface color.

4 CONCLUSIONS AND FUTURE DEVELOPMENTS

The paper has described two interactive AR Apps developed to support users towards a more conscious food consumption in their daily life, as well as to generate awareness about the food waste problem. Specifically, the EGGup Interactive AR App has been developed with the aim of improving the users' engagement and understanding the ecological problem and how they can act to reduce food waste at home. Particular attention has been paid to the design of the application for children with the aim to transmit educational content through an entertainment game.

Moreover, the FOODDY Interactive AR App has been designed and developed with a similar aim. However, in this second case study, the application has been designed to be used during the grocery shopping at the supermarket, to visualize information and data on the environmental impact of food and to support users in adopting correct behaviours.

Proper tests on the educational value of the Apps as well as on users' evaluation of their usability and pleasantness have not been performed yet. Indeed, in order to obtain reliable results from in-depth usability testing sessions, the physical presence of users in the laboratory would be necessary. Unfortunately, due to the Covid-19 pandemic, it has been not possible to carry out this type of activity. Similarly, it was not even possible to carry out the subsequent testing sessions on

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the effectiveness of the presented EGGup systems and FOODDY application in supporting users towards a more conscious food consumption.

Nonetheless, the authors have collected some preliminary comments and opinions from some users (mainly students) that have tried the applications. They reported a very high level of appreciation of the applications and a high level of pleasantness in their use. In particular, they found the AR contents of great entertainment and stimulating to continue using the applications. Moreover, some suggestions about the graphical elements of the interfaces have been collected and used to improve the first versions of the applications. It is worth mentioning that these initial evaluations will certainly need to be properly addressed in the near future.

Regarding the benefits of the presented work, in an envisaged scenario, it can be used as example to design and develop Interactive AR Apps for a wide range of educational purposes concerning ecological, scientific and technological topics, and can be used to support users towards more sustainable behaviours.

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