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Storytelling and remote-sensing playful interventions to foster biodiversity awareness

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Abstract: Different kinds of gameful activities have been successfully exploited to foster engagement and arouse highly motivated behaviour in many areas. A particular type of game, Game with a purpose, has been used in educational contexts, to raise awareness about societal challenges. We envisaged making use of such kind of game in order to foster awareness about biodiversity, in more-than-human urban spaces. The game, named u-Gene, has been designed leveraging on remote-sensing infrastructures to record animals' calls and on the citizen science framework to engage players. Through the game, the player can have fun while incidentally learn about the biodiversity of a specific environment. As a secondary effect of the playful and learning activity, the player can help scientists and researchers in creating a validated dataset of animals' calls, classifying the provided sample. The paper presents the design process, the implementation and the evaluation of our playful intervention, exploiting storytelling and remote-sensing to increase biodiversity awareness. Findings of the preliminary evaluation in the field confirm the potential of our approach.

Keywords: game with a purpose; remote-sensing; biodiversity monitoring; biodiversity awareness; storytelling; bioacoustic sensors

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1 Introduction

Gameful activities are often exploited as motivator tools to elicit and sustain the desired user behavior. In fact, a game, that can be defined as a “problem-solving activity, approached with a playful attitude” (Schell, 2008), is considered one of the most successful ways to create engagement and to arouse high motivated behaviours (Malone, 1981; Cordova and Lepper, 1996). Several studies empirically validate the statement under different scenarios, assessing the positive effect of a game in educational contexts, reporting on its effectiveness as a tool for enhancing the learning and understanding of complex subject matters (Garris et al., 2002). Often, storytelling is a vital aspect of the game in order to create engagement. Thanks to the narrative persuasion construct, it can act as powerful tools to understand the world and how we should live our lives (Green et al., 2004). Moreover, games can be effective in fostering awareness (e.g., De Jans et al., 2017). Several studies investigated how to use games to foster urgent social challenges awareness, such as environmental preservation, energy saving, CO2 emission reduction, to name a few, in order to achieve climate change mitigation (Wu and Lee, 2015; Bang et al., 2006; Goncharova, 2012).

1.1 Motivation

Biodiversity, i.e., biological diversity, is the scientific term used to refer to the variety of life on Earth, including not only species but also ecosystems and differences in genes within a single species (DeLong, 1996). Biodiversity is a relevant concept when referring to environmental preservation: it can be seen as a framework to understand and assess the health of an ecosystem, boosting ecosystem productivity, where each species has a role to play (Sarkar, 2002). Recently, the loss of biodiversity has accelerated to an unprecedented level in Europe and worldwide. In fact, estimates reveal that the current global extinction rate is 100 to 1,000 times higher than the natural rate. This affirmation is supported by strong evidence: in Europe, 42% of European mammals are endangered, together with 15% of birds and 45% of butterflies and reptiles (Alcama and Olesen, 2012). The causes are mostly related to the influence of human beings on the world ecosystem, directly responsible of different activities with negative effects, such as the

conversion of natural habitats through land use changes, pollution, unsustainable use of natural resources, and by making habitats unsuitable for some species (Perrings et al., 1992). However, entirely new ecosystems are emerging and adapting to the new urban habitats. In fact, despite the global decline, there is scientific evidence of the rising number of species in cities that adapt to the new ecological situation, making even more relevant to design more-than-human (smart) cities (Schilthuizen, 2018; Forlano, 2016).

In this context, scientists often resort to volunteers and citizen science for engaging users in biodiversity monitoring, aiming to cover different urban areas and large geographic regions (Schmeller et al., 2009; Cooper et al., 2007). In fact, to halt biodiversity loss, it becomes fundamental to undertake pervasive actions, such as nature conservation efforts and environmental monitoring, to manage natural resources and stimulate awareness and preservation behaviors in citizens, towards an engaged empathy with the more-than-human world (Gruen, 2009; Forlano, 2016). Considering, in particular, the urban environment, these actions can be facilitated exploiting the spread of interconnected sensing infrastructure, able to leverage the internet of things (IoT) paradigm to gather data related to different urban conditions (e.g., Nunes et al., 2017; Vasconcelos et al., 2019; Prandi et al., 2018).

This article builds on findings and insights from a number of research areas, from sustainable HCI (Dourish, 2010), IoT for biodiversity monitoring (Marvin et al., 2016), urban interaction design (Brynskov et al., 2014), games for good (Von Ahn and Dabbish, 2008), and citizens science (Cooper et al., 2007) to set the ground for the design choices behind our intervention. In particular, we investigated how to design a playful activity which leads to motivation as well as to a creative outcome, to foster biodiversity awareness and monitoring, in a smart environment. In doing that, we designed a game with a purpose (GWAP, Von Ahn and Dabbish, 2008), fun to play and, at the same time, that allows collecting useful data for tasks that computers cannot yet or completely perform (according to GWAP definition). In fact, we designed the game, that we named u-Gene, by pursuing a twofold goal:

- 1 Exploiting a remote-sensing infrastructure composed of bioacoustic sensors (that we built and deployed), that collected animal calls which in turn become part of the gameplay; in this way the player can *incidentally learn* (Rieber, 1991) and develop awareness about the biodiversity of the surrounding area.
- 2 As part of the game play, the user, classifies the sounds collected by the acoustic sensors, aiming to create a validated dataset of animals calls.

The rest of the article is structured as follows. Section 2 introduces related work in the area of

- 1 games for biodiversity awareness
- 2 citizens science projects exploiting acoustic sensors for biodiversity monitoring.

Then, we detail the game design process that brought us to conceive, refine and implement the game in Section 3. Some technical details, related to the sensing infrastructure and the u-Gene implementation and mechanics, are presented in Section 4. In Section 5 a preliminary evaluation is presented to drive the discussion. Finally, Section 6 concludes the paper with final remarks and planned future actions.

2 Background and related work

In recent years, taking advantage of emerging technologies and citizen science projects, much research has focused on the design of experiences centred on biodiversity actions, nature awareness, and conservation in urban settings.

Sandbrook et al. (2015) classify digital games for biodiversity conservation in three main clusters, considering the issue they intend to address: education and behavior change; fund-raising; and promoting research, monitoring, and planning.

A pioneering example of game exploiting interactive web-based technologies to educate about biodiversity is *tweet and grow*, launched by The Royal Botanic Gardens of London in 2011. The multi-platform interactive game encourages players to follow Kew Gardens on Twitter and to visit and explore the gardens, which represents a way of modifying real-world behavior through a game (Pett, 2012). Two furthermore recent examples are *Habitat*¹ and ClimACT physical game.² The former one is a multi-platform game that can be played on smartphones, tablets and online. The player's goal is to teach 7 to 12 year olds across the world ecologically sustainable habits and conservation behaviours: the aim of the game is to undertake actions to keep an endangered animal alive (Wu and Lee, 2015). The latter is a role-play game on biodiversity and climate change where players (youngsters between 13 and 17 year olds) represent different characters to discuss a theme related to the conservation of biodiversity and climate change, such as wind energy, native forest, wildfire and water resources. Nowadays, the majority of such digital games exploit emerging and pervasive technologies, from mobile sensing to social media, virtual reality (VR) and augmented reality (AR) techniques. A game exploiting mobile sensing and social media is *Bear 71*,³ a multi-platform interactive social narrative created by the National Film Board of Canada that traces the intersection of humans, nature, and technology. Participants explore and engage with the world of a female grizzly bear through webcams, geolocation tracking, motion sensors, and social media. Another interesting game exploiting AR technology to engage users is *Safari Central*,⁴ a mobile application that allows users to visualise 3D models of different animals on their smartphones. The company, called Internet of Elephants, was founded with the purpose of making wild animals part of daily life for millions of people currently unconnected to wildlife, while generating a new revenue stream for conservation. The animals in the game are the virtual representation of existing animals living in the wild. In fact, these animals are tracked by researchers in order to understand better and monitoring their behavior.

To tackle issues related to real-world scenarios, bioacoustic sensors have been exploited to collect biodiversity data in the field. The majority of such projects were built upon the idea to explore the citizen science paradigm in order to engage a large number of users. Examples of such projects that attracted the attention of citizens are: *iBat*,⁵ *Bat Detective*⁶ (Mac Aodha et al., 2018), and *New Forest Cicada Hunt*⁷ (Pantidi et al., 2014).

The first two projects (iBats and Bat Detective) focus on bats, important indicators of habitat quality and climate change thanks to their sensitivity to human impact, their slow population growth rate, and their temperature-sensitive hibernation behavior (Jones and MacLarnon, 2001). The iBats project, established in 2006 between the Zoological Society of London and the Bat Conservation Trust, coordinates thousands of volunteers (citizen science) on a global scale: initially involving driving cars along specified survey routes with a bat detector mounted on the roof (Walters et al., 2012),

then, the project evolved through the development of a mobile app (for Android and iPhone OS). Such app allows participants to record sounds, location, and data and share through the iBat platform (Jepson and Ladle, 2015). Bat Detective is an online citizen science project launched in 2012, that relies on volunteers to identify bat calls in audio, recorded exploiting specific technologies (Mac Aodha et al., 2018). In fact, participants can analyse the recorded sound by looking at the spectrogram (a visual representation of the audio) and listening to the audio clip, cleaning the dataset removing false positive, i.e., sources that can emit sounds in a frequency similar to bats. The ultimate goal of the project is the creation of a software that automatically extracts the relevant information out of recordings, helping researchers all over the world to track the bat populations. A similar approach has been employed in the LOCOMOBIS project: a low-cost acoustic-based sensing system to monitor and classify mosquitoes (Vasconcelos et al., 2019). This project, developed in the urban settings of Funchal (the Madeira archipelago capital), aims to high-resolution surveillance of mosquitoes to understand their complex ecology and behavior, extremely relevant for mosquito vector-borne disease control efforts. In fact, thanks to advanced bioacoustic sensors, it is possible to detect mosquitoes sounds and classify the species and genders, and citizens and scientists can validate the detection using a web page.

Our approach has been strongly inspired by the above-presented research projects, considering, in particular,

- 1 the use of digital games and storytelling to educate about biodiversity
- 2 the power of the citizen science framework to engage large community in classifying data
- 3 the advances in bioacoustic sensors and remote-sensing infrastructures to collect data in the field.

We combined these three concepts to devise a novel intervention to boost biodiversity conservation, engaging the general public to contribute to the cause.

3 The game design process

This Section describes the design process that brought us to define the storytelling and game mechanics behind the playful intervention, exploiting our remote-sensing infrastructure.

3.1 The objectives and methodology

We embraced the GWAP framework and the involvement of players as citizen scientists, in categorising and analysing data, with the aim to provide fun and knowledge in exchange of time and efficiency. In particular, the three main objectives that drove our design process are:

- 1 (incidentally) educate users about environment biodiversity while playing: the user should learn and be informed about biodiversity variety and changes in locations where the sensors are installed

- 2 engaging and motivating citizen scientists in data categorisation and analysis through a gameful experience
- 3 crowdsourcing the validation of the collected data in order to obtain an accurate dataset of classified animals calls that researchers and scientists can exploit for biodiversity monitoring.

It is worth mentioning that we designed the game focusing on the specific target audience of young-adults with a developed interest in nature, fauna, and flora.

The design process was comprised of three phases: two concept ideation sessions; a focus group session; and, finally, an experience prototype (EP, Buchenau and Suri, 2000). More details about the design process can be found in Loureiro et al. (2018).

3.2 *The concept ideation and focus group sessions*

To start brainstorming and to define some initial game ideas, we conducted two concept ideation sessions, involving two different targets, respectively:

- 1 ten PhD students enrolled in the interaction design and HCI course of the computer science and engineering PhD program
- 2 seven experts in game design and multimedia entertainment (researchers and PhD students in the digital media program).

Each session lasted one hour. It started with a brief introduction to the motivation and objectives of the game to design, and the introduction of our bioacoustic sensors infrastructure, designed to collect acoustic samples of animals calls.

Table 1 Game design dimensions

| <i>N.</i> | <i>Title</i> | <i>Description</i> |
|-----------|------------------------------------|--|
| D1 | Remote-based vs. location-based | This dichotomy highlights the possibility to play outside in defined locations (location-based) or everywhere (remote-based). |
| D2 | Sensors role in the game | Sensors as tools that enable the player to participate in the game (proximity-based game activities) vs. sensors as a remote provider of data. |
| D3 | Real-time data vs. historical data | The first scenario implies having animals and events happening during play time; the second provides more flexibility. |
| D4 | Animal species | Focusing on one specific animal (i.e., iBat) vs. the attempt to create game scenarios that can be generalised for different animals. |
| D5 | Pastime vs. storytelling | Creating mini-games to collect points/engage the player vs. creating of a complex story. |
| D6 | Trustworthiness model | Trusting all the users in the same way vs. creating a validation model to assess the user's credibility (Prandi et al., 2017). |

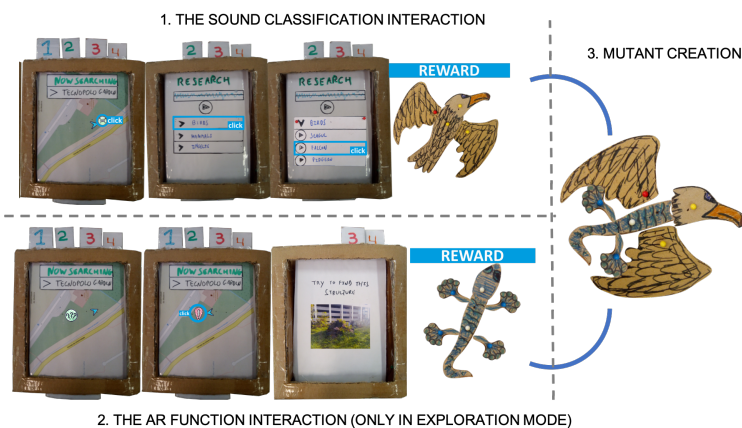
Different game ideas emerged during the sessions, addressing different design dimensions (briefly presented in Table 1).

After considering the pros and the cons of the different game approaches on the light of the design dimensions, we selected one game and a background story as the more promising in addressing our objectives.

The story frames the game as a quest motivated by a distant future disaster, where human actions modified climate and environment to the point of warping habitats achieving worldwide animal extinction. The player is part of a future-based society with access to very advanced technology (like time-travel machines and high-tech drones). An effort is made to repopulate the environments of the (twisted) present by going back to the past where to collect animal DNA samples (captured from animals living in the past, see Figure 1, on the top), and sending them back to the present where the different DNA samples can be creatively combined to make birth to mutants (with specific characteristics) able to survive in the twisted present environment (see Figure 1 – mutant creation). Creating and collecting different types of creatures (mutants) through capturing DNA samples is a positive challenge we came up with to reward the player for her/his actions (i.e., correct sound classification).

The acoustic sensors deployed in real parks and public gardens provide the game fields. When the game starts, the player can select one of the parks, represented in the game, where the sensors are deployed and start playing. On the basis of the player GPS position, it is possible to play locally (location-based mode) or online (remote-based mode). In the latter case, the player needs to be located in a close proximity of the selected park, otherwise, the remote-based mode will start. In both the scenarios, the goals of the game are the same, the only difference is that, in the location-based mode, to further engage users in the outdoor exploration and make the experience more enjoyable, we decided to provide users with an AR function displaying a 3D model of the encountered species (flora or fauna) on the spot. The idea was to provide flora and fauna images and ask the player to find it in the park, guided by the game. Once found the specific plant or animal, the player can exploit AR to capture it and gain special points together with the animals DNA samples. This interaction is visualised at the bottom of Figure 1.

Figure 1 The main game mechanics represented using the paper mockups used during the EP (see online version for colours)



The game concept was presented in a focus group session, engaging eight researchers, experts in game design, multimedia entertainment, digital media, locative storytelling, and HCI and sound, with the aim of criticising and refining the game concept and mechanics. The session was driven by mockups to visually explain the different game mechanics and the mechanics-dynamics-aesthetics (MDA) framework (described in Hunicke et al., 2004).

At the end of the focus group session, the game was refined, applying the feedback and ideas gathered from the experts. The final idea encompassed: both location-based and remote-based mode (D1); use sensors as providers of data (D2); exploiting real-time data and historical data (D3); consider different species of animals to cover the peculiarities of each environment (D4); exploiting storytelling (D5); compute a user's credibility value (D6).

3.3 The experience prototype evaluation

After refining the game concept and gameplay we evaluated it through an experience prototyping (EP) session (Buchenau and Suri, 2000), using a mixed methods approach to collect qualitative data (through observations, personal interviews) and quantitative data (through a questionnaire). EP is a technique borrowed from service design where the early low fidelity (lo-fi) version of the prototype is staged to test its flow, experience, gameplay, and lo-fi user interface. Users are engaged and cast as players, while the researchers perform all the game functions thanks to reenactments, improvisational theater, and Wizard of Oz testing techniques.

For the game EP, 4 researchers in total coordinated the prototype and the evaluation. 14 young-adults attending the master of interactive media design, hence very familiar with game design techniques and interactive storytelling, were recruited as users (seven females and seven males), ranging from 21 to 30 years old. We organised the EP session in the local University Biodiversity garden, rich in plants and animals, representing a perfect location for our game experience. We focused on the endemic animals that inhabit that environment, such as a *Red-footed maderensis* falcon (for sound classification), a *Podarcis muralis* lizard and a *Hipparchia maderensis* butterfly (associated to the specific plants, exploiting the AR feature).

The EP was constructed using low-fi paper prototypes for the interfaces (as shown in Figure 1) and researcher intervention as a Wizard of Oz style. Each session lasted 15 minutes (on average). The researcher conducting the session acted as a storytelling voice (i.e., the scientist leading the advanced society) assisting the user while playing; two further researchers assisted taking pictures and observation notes, and performing the interviews, after each user's session.

At the end of each session, we interviewed the participants, asking them seven questions regarding the scope, the value, the mechanics, the touch-points, the visual elements, the language and terminology used in the game experience, and suggestions to improve it. After the experience, we sent participants an online questionnaire including a few general questions (name, gender, age, education); two questions about their game behaviour (how often they play and motivation for playing); five items related to interest in nature and hiking; three items related to the experience prototype session.

From the analysis of real-time pictures and notes, and questionnaires we can conclude that all the participants enjoyed both the EP session and the game itself. In general, users found the game interesting, easy to play and with a clear scope. This

was documented through the interviews and questionnaires. Looking into the qualitative data, confirmation of users' enjoyment and incidental learning effect of the game can be found in the following user claim: "It felt like a fun way to explore an area and learn about the fauna, and will probably help identify animals after using it." Another one affirmed: "I appreciate the experience [...] I think it was interesting and, at the same time, didactic." Moreover, when queried about the possibility to continue to play with the game, a user answered: "Yes! Because it keeps me motivated and that is an interesting/different point of view." This is confirmed by the fact that 50% of users declared that they will like to play the game once fully implemented, while another 35% reported that they are not sure, but if asked they would try it. This information becomes of interest if correlated with the users' personal data, which tell us that the engaged participants are not hardcore game player (in fact, none of the users plays every day, and the majority of them play one per month or less).

Considering the location-based mode, the majority of the users told us that, while hiking, 41.7% use the phone when it's needed, 33.3% use it sometimes. This tells us that there's space for the game to be played during their hiking activities. A majority of users also revealed they use digital maps on their hikes (33.3% use only digital versions and 25% use physical and digital copies). This raises the possibility for our game to also work as an orientation tool, guiding players through a park.

Regarding the remote-based mode, 58% of users (surprisingly) claimed that they would prefer the remote mode, while 25% would prefer the location-based mode, leaving 17% of users that would prefer a mix of both the game modes. This is an interesting finding considering our target audience (users passionate about nature, fauna, and flora).

Regarding the game interactions, the two most appreciated features were related to the discovery, and the creation of new species. In fact, some users appreciated the '*discovering the animals through sound*', others appreciated the possibility of '*creating a new species*'. Moreover, the topic of the game itself was greatly appreciated. In fact, one user claimed: "The topic is very interesting and warns about the consequences of what is happening today."

4 The game walkthrough

In this section, we present the technical aspects of our system, including the remote-sensing infrastructure and the mobile application, describing the client-server architecture. Moreover, the game interfaces are presented.

4.1 The remote-sensing infrastructure

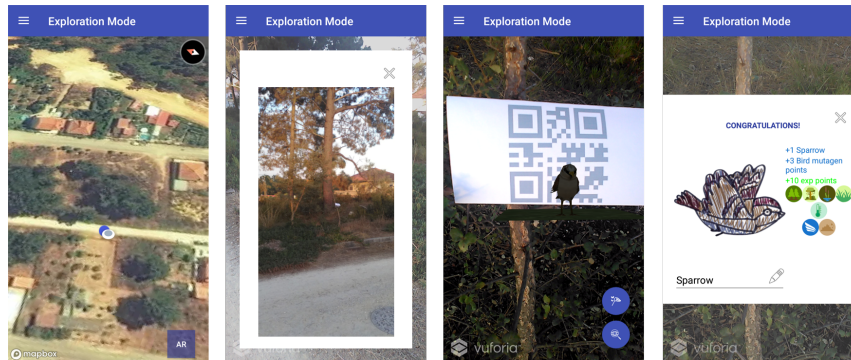
The overall system architecture of the system is comprised of

- 1 the bioacoustic sensors infrastructure
- 2 the GWAP application.

Regarding the remote-sensing infrastructure, each node is a low-cost bioacoustic sensor able to detect animals' sound. We designed and built the bioacoustic sensor on the basis of LOCOMOBIS, a low-cost sensors build with the aim of detecting different species of

mosquitoes based on their frequency, as presented in Vasconcelos et al. (2019). Such a sensor was built with a low-frequency microphone (used to detect and capture mosquito sounds). We replaced it with a microphone with a specific frequency range, based on the animals calls we are interested to capture (with an ultrasonic microphone for detecting high-frequency bats' calls, and so on).

Figure 2 An example of the implemented AR function (see online version for colours)



4.2 The game implementation

We developed the system architecture as a functional system, able to support multiple users playing our game using an Android OS mobile application. To do this we implemented a server using Droplets from Digital Ocean,⁸ flexible Linux-based virtual machines (VMs) that run on top of virtualised hardware. To support the HTTP communication, we used the OkHttp⁹ library to enable the game to send and receive HTTP messages, and we implemented multiple Java Servlets supported by the Apache Tomcat Server.¹⁰

We implemented servlets to deal with the following requests:

- 1 creating account
- 2 logging in
- 3 requesting game data (the player's game progress data)
- 4 uploading game data (to store in the player's folder including the player's game data and the captured audio)
- 5 requesting captured audio information
- 6 requesting audio sample
- 7 sending sample classification (the name of the audio file the player classified, her/his classification and her/his reliability score).

The application side (Android mobile app) maintains the player's current game progression in the smartphone storage. In particular, the application maintains JSON files with the following data:

- 1 account information (such as the player's level, experience points)
- 2 drones (i.e., virtual drone position in the remote environment)
- 3 timelines (information about the weeks the user already analysed, the percentage of analysed sounds in each week, and so on)
- 4 classified and unclassified samples
- 5 habitat progression (including the completion percentage, the mutants that were placed in the habitat and if the habitat is unlocked)
- 6 mutagen points (the type and amount of mutagen points gained by the player to use to create mutants)
- 7 the mutants (the list of mutants the player has created and captured).

The application uploads the player's game data to the server each time the game closes. The server stores the player information (username, email and password) and the sample classifications (the audio file name, the username of the classifier, the classification and reliability score) in the SQL database.

To implement the location-based game mode, we used the Google Maps SDK (to visualise the user's position and the points of interest in the map) and the Vuforia¹¹ engine (AR SDK) and Unity (game engine). This enabled us to render 3D scenes through a portable smart device's camera onto a given image target (in this case, we used QR codes).

4.3 *The game mechanics*

After the log in, the user can start playing. By default, the game starts in the remote-based mode, called *drone dispatcher mode*, and changed to location-based mode, called *exploration mode* when the user is close to one of the available parks (where our sensors infrastructure is actually installed). Considering the location-based mode, when the player is physically nearby one of the parks available in the game, a button will appear in the drone dispatcher screen. This button enables the player to enter the exploration mode. In exploration mode, the interface shows the time and place the player currently is, as well as the corresponding data. The map also shows the player's current position.

Considering the drone dispatcher mode (i.e., remote-based mode), the player has the ability to change parks using the park selector menu and s/he has also the possibility to travel through time within a week. This is achieved by selecting the timeline graph bars or by using the arrows on top of the graph. This graph, located at the bottom of the screen, presents different information. By default, the graph shows the number of possible animals' calls detection per day in a given week. It also shows the current date the player is accessing, and the corresponding day of the week. The player can choose the information the graph shows via the graph options menu. This menu is hidden off screen below the graph. The player can access it by sliding the graph up with the finger, gaining access to the options. The player can display the number of located animals, the number of collected samples or both. S/he can display this data throughout a given week or focus on the current day s/he is accessing, seeing the located animals and collected samples of that day, organised by hours. Through this graphic element, players have a

very comprehensive visual display of the amount of animals that exist in an area, as well as at the time of day they're most active. This feature allows the player to become more aware of biodiversity variations and changes during the time (in a day, by month, by year, etc.) in a specific park (biodiversity monitoring).

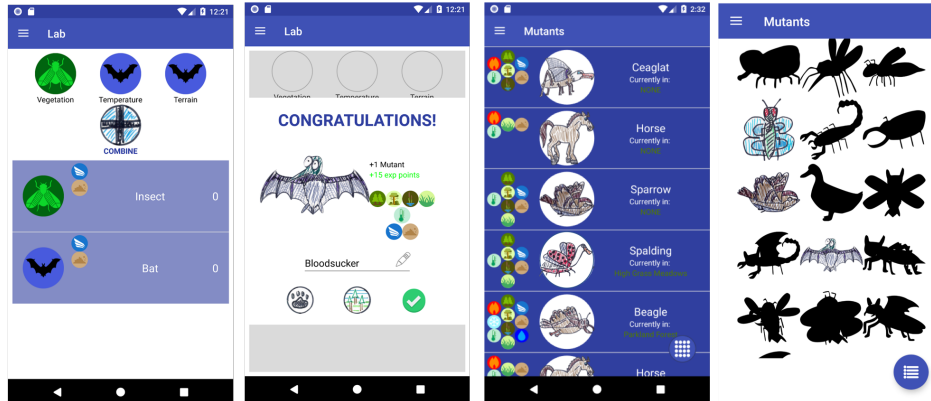
In the game, there are two typologies of point of interests, both exploited in the game to foster biodiversity (incidental) learning and awareness.

- 1 *Augmented points* that are locations only reachable in the location-based mode, where the AR feature is exploited to collect a special animal DNA sample and experience points (see Figure 2). The player can capture (virtual) animals via the exploration game mode, by getting close to a point of interest. When the player gets close enough (around 20 metres) the phone will vibrate and ring, and the interest point marker will turn into a button. By clicking the button the player will enter the search mode that provides hints of what s/he should be searching for in that area. When the player finds the specific location, s/he should look for a QR code. When pointing the camera to the QR code the player will be able to see a 3D model of an animal in AR. When the animal appears, the player has the ability to capture the animal and gain some mutagen special points and experience points.
- 2 *Research points* are the digital representation of the bioacoustic sensors physically located (using the same coordinates) in a park and are really important in the gameplay, since they allow the player to listen and classify the animals calls (the main objective of the game). These research points can be reached both in the location-based mode, by walking close to the sensor location (around 20 metres), and in the remote-based mode, using the virtual drone. This drone is the advance tool that enables a player to travel back in time (in the far way past) and search for animal samples. After placing (drag-and-drop) a drone in a research point, it will be transformed into a button and the phone will vibrate, indicating to the player that a drone collected a sample for the player to analyse. As anticipated, in the exploration mode this is achieved by proximity. When a player gets near enough a research point (around 20 metres) the marker will change to a button, the phone will vibrate and play a sound (similar to a bell ringing), indicating to the player that s/he is close enough to collect the data and analyse it. In both the modes, research points labelled as 'available' have data that the player has not classified yet and 'unavailable' research points have no new data for the player to classify.

The animal sounds classification is done through the research screen interface. We provide the user with four sound to classify. The sample plays automatically, but the player can use the play button again to hear it different times. After listening to the sample, the player uses the cross-reference library to try and identify the sound. The cross-reference library is divided into general categories. Each category has an expandable list of sounds related to that category. When the player selects an item of this list, the corresponding sound plays. This allows the player to try and match the sample s/he is analysing. We knew that asking players to make a taxonomic identification of a species by sound alone is too complicated, so we just ask them to identify the general species of the animal they are listening to (e.g., bat, insect, bird). This solution still allows us to obtain accurate and relevant information. Mutagen and experience points

are given on the basis of how well the player identified the sounds. The mutant creation is presented in Figure 3.

Figure 3 The mutant creation implemented interaction (see online version for colours)



When players have sufficient mutagen points, they can create mutants using the mutant incubator (the *Lab* screen) and place them in a habitat with specific characteristics. This mechanic is accessible through the drawer menu. The player can also access to the mutants s/he created/captured through the mutants interface, accessible through the drawer menu. This interface also provides the player with information about their mutants (name, characteristics, current habitat, and image). In the *Lab* screen, the player is presented with three circular slots. These slots will determine the mutant's design but also its characteristics. The slots determine:

- 1 Vegetation: The mutant's head and what type of vegetation the mutant can survive in).
- 2 Temperature: The mutant's body and what temperature the mutant can sustain.
- 3 Terrain: The mutant's limbs and in what kind of terrain the mutant can traverse.

The slots are occupied by the mutagen points the player collected. Each type of mutagen (i.e., DNA samples) confers specific characteristics to the mutant. The player places the mutagens in the slots by touching the specific mutagen s/he wishes to use and the mutagen will occupy the currently selected slot. When the player fills all the slots, a button will appear, allowing the creation of the mutant to take place.

After the mutant is created, the player can see what characteristics it possesses, give it a different name, and place the mutant in a habitat (through the habitat interface). The habitat interface provides players with different habitats (some already unlocked, others to unlock gaining experience points). Each habitat has specific characteristics making this environment livable only by mutants created combined specific features in terms of vegetation, temperature, and terrain. In this way, the player is encouraged to visit different parks inhabited by different animal species to collect several mutagens points, corresponding to different DNA samples. Visiting existing parks (location-based mode), the collection of mutagens can become richer, thanks to the AR function. Moreover, to keep users engaged, we also defined a habitat as completed once inhabited by a certain

number of mutants able to survive in that environment (defined as the capability of the habitat). Once completed, the player gains a reward, a new animal which DNA sample can be used to create mutants and populate new (unlocked) habitats.

The drawer menu also shows information regarding the player, namely her/his username, level and experience bar. The player can gain experience points to fill the experience bar by doing different tasks. Each time the player level ups, s/he gains one more drone to use in her/his research. The player's level equates to the number of drones s/he has.

5 Preliminary evaluation and discussion

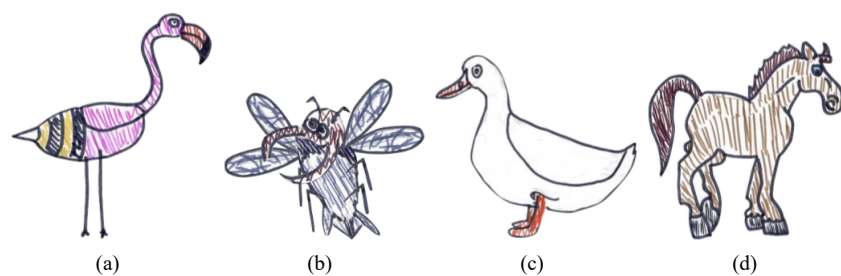
u-Gene was tested to assess the game mechanics, and the system usability and user experience. Attention was paid to assess if the system worked as a gameful experience (GWAP) geared towards classifying animal sounds and biodiversity monitoring.

5.1 Methodology

The sessions took place in the proximity of the Instituto Superior Tecnico (IST), in Lisbon, Alameda. In this area, the sensors infrastructure composed of two bioacoustic sensor stations to detect animals calls was deployed.

We tested the game scenario inviting players to go to a specific week in the past (for testing purposes the week of the 24th to the 30th of September 2018 was chosen, because of its richness of detected animal calls). In this week, the sensors deployed in that area (research points) detected animals call, with a total of 16 samples for players to classify. To engage users in the location-based mode, we included two augmented points in the area (i.e., AR function).

Figure 4 Some mutants players created during the evaluation session, (a) flabeego (b) bleedtle (c) duck (d) horse (see online version for colours)



During the session, we applied the thinking aloud method in order to collect participants' thoughts about the game and also check for misconceptions or misunderstandings caused by the interface elements (Jørgensen, 1990). During the session, one researcher assisted the player, taking notes and helping in case of need. After the session, the researcher interviewed the player to grasp other details about the experience, including questions about the game context, the interfaces, and the game mechanics.

To collect qualitative data about the participants, we provided them with a questionnaire (structured as described in Subsection 3.3), while, to collect qualitative data about the game interaction, we recorded the game sessions, including all the activities and events the player performed in the screens.

We gave players two objectives:

- 1 find and capture an animal, exploiting the AR feature
- 2 re-populate the Parkland Forest habitat (a virtual habitat we create for the test), giving freedom to the player to explore the game as they wished.

The researchers provided the participant with an Android smartphone and headphones, so they could listen carefully to the sounds. Users started the game watching a short walkthrough tutorial (encapsulated into the mobile app), as to learn how to change parks, time-travel within the week, place drones, classify sounds, create mutants and re-populate habitats.

5.2 Results

We selected seven young-adults interested in nature (accordingly with the game target audience) ranging from 20 to 26 (two females and five males) to test our game. Play sessions lasted an average of 20 minutes. Seven people contributed to the classification of 11 sounds. Out of those classifications, seven were single contributions (meaning only one person classified them).

Analysing in detail the session observation, we noticed that only two users time-travelled in different days of the week, looking for more research points; two users lost the drone. Moreover, two players thought that the drone was a single-use object to be used just one time in the game. In both the cases, participants did not realise the drone was still in the previous spot, searching for more animals to collect samples. This issue could be easily fixed by returning the drone to the player each time the player concludes the sound classification.

When entering the exploration mode, most of the players (4) had no problem in using the map to reach the location of the markers. Three players expressed difficulties in finding the markers they were looking for. The researcher wrote the following: The player passed by the point she was looking for and said “I’m still far away. I have to go up.” Realising she was moving away from the marker and she exclaimed “Oh no, it’s further down! I’m bad at this!” It is worth to note that these three players admitted to not have a great sense of orientation while using a map, moreover the GPS tracking of the phone was very irregular, it took a while to update and show the player’s current position.

Some of the players drew comparisons with Pokémon Go,¹² as annotated by the researcher: The player is walking to a research point; exclaimed “This is so cool. It’s like a cuter version of Pokémon Go.” When players found the augmented point where they could capture an animal, 6 out of 7 participants were visibly excited when seeing the 3D model of the animal. One participant talked with the animal, saying “Hello! You’re so cute! I want to catch you!” One participant simply exclaimed “This is so cool!” After capturing the first animal, a player asked to the research: “There’s another one, right? Can I go catch it?”

Considering the sound classification, almost all players seemed rather confused and tentative on their first sample classification task. This result is not surprising since users were not used to listening to animal calls. From the research emerged that the more the user played the more was accurate and efficient in classifying the sound s/he became, learning from past experiences. In fact, one player claimed: “I remember hearing this one! It’s a bat!”

All players enjoyed the process of creating new animals. Some of the mutants/animals the participants obtained during the session are presented in Figure 4. One player laughed at all the animals he created as well as their names: after creating a mutant, a player started laughing and saying “Flabeego? Because it’s a bee and flamingo together, right? That’s cool!” One player obtained a mutant named Bleedtle and, smiling, exclaimed “Oh, he’s ugly. I don’t like it!” while another participant obtained a duck and exclaimed “Nice! I got a duck!” Interesting to note that two players after reaching their goals continued playing because they wanted to create more mutants.

We set the capability of the Parkland Forest habitat (the habitat created for the test session) to two to encourage users to create at least two mutants and let them experience the reward, obtained once reached the capability of the habitat. The reward was the horse represented in Figure 4. Players were excited about the possibility of unlocking the reward. In fact, one player, after having received the reward, exclaimed in disbelief “I won a horse? I won a horse! I bet I can put it in the next habitat!” These results highlight that the progression system with rewards, implemented in the habitats screen, was having its intended effect.

During the post-session interview, we asked some questions related to the game context. In particular, we asked for a brief description of the story. Four players were able to retell the story, including some detail. The other three players were able to give the gist of the story, living out some details. Moreover, we asked if they understand their role in the game: five people responded correctly and two people left out some details.

Most of the players enjoyed the background story motivating the gameplay. Regarding the theme of nuclear war and climate change, one player said “I think it is an interesting context since it’s kind of a possible. Climate change, nuclear war are real threats”, another player also stated “It reminds of a movie. And nuclear fallout and extinction are definite concerns on everybody’s mind.”

The most enjoyable part of the experience revolved around catching and/or creating animals. Two players enjoyed classifying sounds the most. One player appreciated the fact he could choose between playing from far away (through the drone dispatcher mode) and on location (through exploration mode).

Regarding the incidental learning part of u-Gene, five users declared they were shocked there were so many species of bats and also the sound of bat calls was new to some of them.

In the end, we asked all participants if they would download the game and play it in the future. Five out of the seven participants said ‘yes’ and the other two participants responded with ‘maybe’. We take comfort in these responses because, according to the questionnaire, even the players who might download the game or not, they reported not liking video and computer games in general, highlighting how despite some user interface issues, playing our game was an overall enjoyable experience.

This evaluation has clearly several limitations: the limited number of users; the player was exposed to the game only for short sessions of 20 minutes each (on

average), and asked to complete only two of the tasks assigned by the overall game. Nonetheless, the findings emerging from the study are encouraging. In particular, the results demonstrate the possibility to use storytelling and remote-sensing to stimulate biodiversity awareness, exploiting incidental learning. Regarding the other objective, i.e., creating a dataset of validated animals calls, despite the initial difficulties players demonstrated to learn by doing, and increase their ability while playing, confirming the feasibility of reaching such aim.

6 Conclusions and future work

We present our bioacoustic-powered playful intervention to foster biodiversity awareness towards more-than-human urban environments. In particular, we designed a game with a purpose in order to address two main objectives:

- 1 foster biodiversity awareness exploiting incidental learning while having fun – the user should learn and be informed about the variety of biodiversity and its changes in the locations where the sensors are installed
- 2 involving and engaging users in data classification (animal calls) to help researchers to validate the animals detections and obtaining a dataset of classified animals' calls.

Following a game design process composed of different phases, such as concept and gameplay ideation, testing, and EP, refining and implementing, we defined, the game background, the storytelling and the game mechanics of the game.

Accordingly, we evaluated the overall concept and experience flow through an experience prototype involving 14 users before implementing the game and evaluating the system with further 7 users, obtaining the confirmation that the designed game can be effective in reaching the two defined objectives.

As future work, we need to refine u-Gene, in particular, the graphical interface of the game that was the part more criticised in the evaluation sessions, to render the game more appealing. Eventually, we plan to make the mobile app freely available on the Google Play store so we can attempt to a wider and easier evaluation of the game, without having to provide our own devices to the users.

Moreover, we would like to develop the creative aspect of the game, allowing users to create (sketch) their own mutants and sharing these small pieces of art with the other players.

References

- Alcama, J. and Olesen, J.E. (2012) *Life in Europe Under Climate Change*, Wiley Blackwell, Chichester, UK.
- Bang, M., Torstensson, C. and Katzeff, C. (2006) 'The powerhouse: a persuasive computer game designed to raise awareness of domestic energy consumption', in *International Conference on Persuasive Technology*, Springer, pp.123–132.
- Brynskov, M., Carvajal Bermúdez, J., Fernández, M., Korsgaard, H., Mulder, I., Piskorek, K., Rekow, L. and De Waal, M. (2014) 'Urban interaction design: towards city making', Urban IxD Booksprint, Neuhausen, Germany.

- Buchenau, M. and Suri, J.F. (2000) 'Experience prototyping', in *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, ACM, pp.424–433.
- Cooper, C., Dickinson, J., Phillips, T. and Bonney, R. (2007) 'Citizen science as a tool for conservation in residential ecosystems', *Ecology and Society*, Vol. 12, No. 2, pp.11–21.
- Cordova, D.I. and Lepper, M.R. (1996) 'Intrinsic motivation and the process of learning: beneficial effects of contextualization, personalization, and choice', *Journal of Educational Psychology*, Vol. 88, No. 4, p.715.
- De Jans, S., Van Geit, K., Cauberghe, V., Hudders, L. and De Veirman, M. (2017) 'Using games to raise awareness: how to co-design serious mini-games?', *Computers & Education*, July, Vol. 110, pp.77–87.
- DeLong, D.C. (1996) 'Defining biodiversity', *Wildlife Society Bulletin*, Vol. 24, No. 4, pp.738–749.
- Dourish, P. (2010) 'HCI and environmental sustainability: the politics of design and the design of politics', in *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, ACM, pp.1–10.
- Forlano, L. (2016) 'Decentering the human in the design of collaborative cities', *Design Issues*, Vol. 32, No. 3, pp.42–54.
- Garris, R., Ahlers, R. and Driskell, J.E. (2002) 'Games, motivation, and learning: a research and practice model', *Simulation & Gaming*, Vol. 33, No. 4, pp.441–467.
- Goncharova, M. (2012) 'Planet play: designing a game for children to promote environmental awareness', *Online Journal of Communication and Media Technologies*, Vol. 2, No. 4, pp.137–154.
- Green, M.C., Brock, T.C. and Kaufman, G.F. (2004) 'Understanding media enjoyment: the role of transportation into narrative worlds', *Communication Theory*, Vol. 14, No. 4, pp.311–327.
- Gruen, L. (2009) 'Attending to nature: empathetic engagement with the more than human world', *Ethics & The Environment*, Vol. 14, No. 2, pp.23–38.
- Hunicke, R., LeBlanc, M. and Zubek, R. (2004) 'MDA: a formal approach to game design and game research', in *Proceedings of the AAAI Workshop on Challenges in Game AI*, Vol. 4, p.1722.
- Jørgensen, A.H. (1990) 'Thinking-aloud in user interface design: a method promoting cognitive ergonomics', *Ergonomics*, Vol. 33, No. 4, pp.501–507.
- Jepson, P. and Ladle, R.J. (2015) 'Nature apps: waiting for the revolution', *Ambio*, Vol. 44, No. 8, pp.827–832.
- Jones, K.E. and MacLarnon, A. (2001) 'Bat life histories: testing models of mammalian life-history evolution', *Evolutionary Ecology Research*, Vol. 3, No. 4, pp.487–505.
- Loureiro, P., Prandi, C., Nunes, N. and Nisi, V. (2018) 'Citizen science and game with a purpose to foster biodiversity awareness and bioacoustic data validation', in *Interactivity, Game Creation, Design, Learning, and Innovation*, Springer, pp.245–255.
- Mac Aodha, O., Gibb, R., Barlow, K.E., Browning, E., Firman, M., Freeman, R., Harder, B., Kinsey, L., Mead, G.R., Newson, S.E. et al. (2018) 'Bat detective – deep learning tools for bat acoustic signal detection', *PLoS Computational Biology*, Vol. 14, No. 3, p.e1005995.
- Malone, T.W. (1981) 'Toward a theory of intrinsically motivating instruction', *Cognitive Science*, Vol. 5, No. 4, pp.333–369.
- Marvin, D.C., Koh, L.P., Lynam, A.J., Wich, S., Davies, A.B., Krishnamurthy, R., Stokes, E., Starkey, R. and Asner, G.P. (2016) 'Integrating technologies for scalable ecology and conservation', *Global Ecology and Conservation*, July, Vol. 7, pp.262–275.
- Nunes, N., Ribeiro, M., Prandi, C. and Nisi, V. (2017) 'Beantalk: a community based passive Wi-Fi tracking system for analysing tourism dynamics', in *Proceedings of the ACM SIGCHI Symposium on Engineering Interactive Computing Systems*, ACM, pp.93–98.

- Pantidi, N., Moran, S., Bachour, K., Rodden, T., Zilli, D., Merrett, G. and Rogers, A. (2014) 'Field testing a rare species bioacoustic smartphone application: challenges and future considerations', in *2014 IEEE International Conference on Pervasive Computing and Communication Workshops (PERCOM WORKSHOPS)*, IEEE, pp.376–381.
- Perrings, C., Folke, C. and Mäler, K-G. (1992) 'The ecology and economics of biodiversity loss: the research agenda', *Ambio*, Vol. 21, No. 3, pp.201–211.
- Pett, D. (2012) 'Uses of social media within the British museum and museum sector', in C. Bonacchi (Ed.): *Archaeology and Digital Communication: Towards Strategies of Public Engagement*, Archetype Publications, London, UK, pp.83–102.
- Prandi, C., Mirri, S., Ferretti, S. and Salomoni, P. (2017) 'On the need of trustworthy sensing and crowdsourcing for urban accessibility in smart city', *ACM Transactions on Internet Technology (TOIT)*, Vol. 18, No. 1, p.4.
- Prandi, C., Nisi, V., Villaflor, R., Liao, S., Best, B., Gavina, V. and Nunes, N. (2018) 'On designing a way-finding system to assist users with respiratory ailments and track symptoms', in *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*, ACM, pp.47–54.
- Rieber, L.P. (1991) 'Animation, incidental learning, and continuing motivation', *Journal of Educational Psychology*, Vol. 83, No. 3, p.318.
- Sandbrook, C., Adams, W.M. and Monteferri, B. (2015) 'Digital games and biodiversity conservation', *Conservation Letters*, Vol. 8, No. 2, pp.118–124.
- Sarkar, S. (2002) 'Defining 'biodiversity'; assessing biodiversity', *The Monist*, Vol. 85, No. 1, pp.131–155.
- Schell, J. (2008) *The Art of Game Design: A Book of Lenses*, Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.
- Schilthuizen, M. (2018) *Darwin Comes to Town: How the Urban Jungle Drives Evolution*, Picador, New York, NY, USA.
- Schmeller, D.S., Henry, P-Y., Julliard, R., Gruber, B., Clobert, J., Dziock, F., Lengyel, S., Nowicki, P., Deri, E., Budrys, E. et al. (2009) 'Advantages of volunteer-based biodiversity monitoring in Europe', *Conservation Biology*, Vol. 23, No. 2, pp.307–316.
- Vasconcelos, D., Nunes, N., Ribeiro, M., Prandi, C. and Rogers, A. (2019) 'Locomobis: a low-cost acoustic-based sensing system to monitor and classify mosquitoes', in *2019 16th IEEE Annual Consumer Communications & Networking Conference (CCNC)*, IEEE, pp.1–6.
- Von Ahn, L. and Dabbish, L. (2008) 'Designing games with a purpose', *Communications of the ACM*, Vol. 51, No. 8, pp.58–67.
- Walters, C.L., Freeman, R., Collen, A., Dietz, C., Fenton, M.B., Jones, G., Obrist, M.K., Puechmaille, S.J., Sattler, T., Siemers, B.M. et al. (2012) 'A continental-scale tool for acoustic identification of european bats', *Journal of Applied Ecology*, Vol. 49, No. 5, pp.1064–1074.
- Wu, J.S. and Lee, J.J. (2015) 'Climate change games as tools for education and engagement', *Nature Climate Change*, Vol. 5, No. 5, p.413.

Notes

- 1 <http://www.habitatthegame.com/>
- 2 <http://www.climact.net/2018/07/11/the-role-play-game-on-biodiversity-and-climate-change/>
- 3 <https://bear71vr.nfb.ca/>
- 4 <https://www.safaricentralgame.com/>

- 5 <https://www.bats.org.uk/our-work/national-bat-monitoring-programme/past-projects/ibats>
- 6 <https://www.batdetective.org/>
- 7 <http://www.newforestcicada.info/>
- 8 <https://www.digitalocean.com/products/droplets/>
- 9 <https://square.github.io/okhttp/>
- 10 <http://tomcat.apache.org/>
- 11 <https://www.vuforia.com/>
- 12 <https://www.pokemongo.com/en-us/>