Citizen Science and Game with a Purpose to Foster Biodiversity Awareness and Bioacoustic Data Validation

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Abstract. Biodiversity refers to the variety of life on Earth and its biological diversity. It boosts ecosystem productivity, where each species has a role to play. Unfortunately, human activity is causing massive extinctions and biodiversity losses continue. Because of that, nature conservation efforts and environmental monitoring have become increasingly important to manage natural resources and reacts to changes. Following this line, we designed a game with a purpose (GWAP) aimed to address two emerging issues in this area: (i) engaging citizens in validating bioacoustic samples collected using smart bioacoustics sensors; and (ii) educating and enhancing the user's biodiversity awareness while playing, inspiring them for later reflection and eventually inspire behavioural changes. In this paper, we describe the different design phases and the insights obtained from an early experience prototype session of the game, engaging 14 young-adults. From the prototype session, we collected insightful feedback on the design of the game and its mechanics as well as its interface. Moreover, preliminary positive responses of the users encourage us to refine and continue developing the game.

Keywords: Biodiversity awareness · Biodiversity monitoring
Citizen science · Game with a purpose · Bioacoustics sensors

1 Introduction

Over the last 100 year, the abundance of species that exist in our environments has been dramatically affected [5]. Humans have been the main harbingers of environmental destruction and modifications, transforming earth systems, and accelerating climate change [9]. Such activities result in biodiversity losses that affect the ecosystem functions, and impacts the goods/services ecosystems provide [4]. In response to this, different organizations are advocating for urgent actions to undertake to limit the effects of this age of the Anthropocene (a

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relevant example is represented by the 10-years plan developed by the United Nations[1]), requiring the effort of stakeholders, policymakers, and citizens.

In this scenario, monitoring species has become increasingly important. The fluctuation of a species population can indicate the general health of the habitat. This type of monitoring is referred as biodiversity monitoring and through it, we can detect rising problems in a habitat, allowing us to find the source of the problem and mitigate the repercussions on the environment [11]. However, biodiversity monitoring is a complex task, both in collecting and analysing biological data. Involving a group of scientists to manually collect and analyse data is not always feasible, considering the location and size of certain habitats and the number of species that inhabit it. The use of technology in collecting and analysing biological data seemed an apparent and scalable solution [6].

Even though technology is enabling scientists to collect and analyse data more efficiently, if the goal is to globally monitor the environment, creating teams of scientist to do so is still not a scalable solution considering the size of the Earth and the number of species that exist in it. To solve this problem, scientists turned to the general public for help, crowdsourcing the collection and analysis of data (e.g., [1,8,14]). Scientists issue instructions for these "amateur-scientist" to follow, enabling them to collect and analyse data without the need for a specific knowledge, while at the same time improving the reliability of the obtained data. This type of projects is referred to as Citizen Science projects, collaborative process in which volunteers work with professional scientists to study real-world problems [10]. In these projects, the number of people who volunteer strongly influences the project's success, and captivating and engaging the general public becomes a key factor in the project's overall success. Participants in this type of projects are often motivated by contributing to actual scientific research. The entertainment aspect is also relevant in motivating the citizens' participation. In fact, adding gaming elements to these projects proved to be a successful way to increase participation, boosting the number of involved citizen scientists [2].

Taking the above into consideration, we designed a gameful experience, exploiting smart bioacoustics sensors and players' inputs to help monitor biodiversity in a given area, through fun and an exciting game activity. Our final aim is to design a Game with a Purpose (GWAP, [15]) that will contribute in the area of HCI and Environmental Sustainability by exploiting the GWAP framework and Citizens Science paradigm. In particular, we are investigating: (i) if the GWAP will succeed in engaging and eventually educate users, increasing their biodiversity awareness about the environment that surrounds them, and (ii) if we can validate a reliable dataset of animal calls, based on player's inputs, so as to use it to monitor a given species population as well as the environment biodiversity. In this paper, we focus on describing the different design phases of the GWAP and the preliminary results from an experience prototyping validation sessions. Given the positive results emerging from the study and the engagement of the users, we are currently developing the GWAP followed by a user study.

[1] https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf.

The rest of the paper presents the related work in the context of Citizen Science projects for biodiversity using bioacoustics sensors, the game design process, and insights obtained from an experience prototyping session. Finally, it concludes with final remarks and future work.

2 Related Work

The collection and analysis of biological data have been key challenges for any project focused on biodiversity monitoring. To solve this issue, some projects rely on the citizen science framework (i.e., [2]). Projects like Bat Detective, iBats, and the New Forest Cicada fall into this category, exploiting acoustic sensors to engage citizens in collecting data for biodiversity monitoring. In particular, Bat Detective [15] is an online citizen science project launched in 2012, that relies on volunteers to identify bat calls in audio samples. Those audio samples were recorded during surveys, which were done by teams of volunteers with specific equipment for the effect. The ultimate goal of the project is the creation of a program that automatically extracts the relevant information out recordings to be used by researchers all over the world, simplifying the tracking of bat populations. Another project focusing on bats is the iBats[2] program, established in 2006 through a collaborative effort between the Zoological Society of London (ZSL) and the Bat Conservation Trust (BCT). The aim of this program is to carry out coordinated volunteer-led bat population monitoring on a global scale. This project is powered by citizen scientist. The iBats development team released an iPhone application which can be directly attached to an ultrasonic detector to record grid references, sound files, and other survey data along the route. The New Forest Cicada Project [16] aims to equip the millions of visitors of the New Forest, a national park on the south coast of England, with a smartphone application that can detect and recognise the song of the cicada. This project aims to discover if the cicada is now extinct in the UK or simply migrated to a yet undiscovered site [16].

Building on these inspiring examples, our approach takes advantage of acoustic sensing and Citizen Science to categorise, validate and map local species and biodiversity, exploiting a gameful experience to motivate users in actively be part of and contribute to the community. In fact, different research works have proved that gameful experiences are powerful tools to engage users to participate in crowdsourcing activities, including both digital tasks (e.g., [15]) and real tasks in the urban environment, exploited as a digital playground (e.g., [13]).

3 The Game Design

Aware of the challenges surrounding the collection and analysis of data for project focused on biodiversity monitoring, including cost and problematic scalability in using scientists and professionals, we embraced the GWAP framework

[2] http://www.bats.org.uk/pages/ibatsprogram.html.

and the involvement of players as citizen scientists, in categorising and analysing data, aiming at providing fun and knowledge in exchange of time and efficiency. In designing the game, we focus on the specific target audience of young-adults with a developed interest in nature, fauna, and flora.

3.1 Objectives and Methodology

Our aim is to create a GWAP that shares acoustic data collected by strategically placed acoustic sensors in order to engage users in categorising and hence learning about fauna and eventually flora biodiversity while contributing to data classification. The three main objectives that the game addresses are: (1) educating 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) Involving and engaging users in data categorization and analysis through a GWAP. (3) Crowdsourcing the validation of collected data in order to obtain an accurate data set of classified animal calls. These three objectives have driven the design process, composed by different phases: two concept ideation sessions (Sect. 3.2); a focus group session (Sect. 3.3); and an experience prototype (EP, [3]) (Sect. 5).

3.2 Concept Ideation Sessions

To start brainstorming and define some initial game ideas, we conducted two concept ideation sessions, involving two different targets: ten PhD students enrolled in the Interaction Design and HCI course of the Computer Science and Engineering PhD programme (Tecnico, University of Lisbon), and seven experts in game design and multimedia entertainment (M-ITI researchers and PhD students in the digital media programme). The sessions lasted 1 hour and started with a brief introduction to the motivation and goals (objectives) of the game to design. Moreover, to inspire them, we introduced some projects where acoustic sensors are used to monitor biodiversity. Several different game ideas came out from the two sessions. However, several design issues emerged (DI).

DI 1. Developing location-based mobile games versus virtual representation of the locations where the data subsist. This dichotomy highlights the use of different devices, mobile and/or desktop based.

DI 2. Using the sensors as tools for enabling the player to participate in the game (proximity-based game activities) versus using the sensors as a provider of data. This would imply different design and game mechanics.

DI 3. Using real-time data gathered from sensors versus using historical data from sensors. The first scenario implies having animals and event happening during play time, which is very difficult to control, but at the same time gives the game a certain "magic moment" event, when real animals are spotted while capturing and categorizing their sounds, during the game play.

DI 4. Focusing on one specific animal versus the attempt to create game scenarios that can be generalized for different animals. The game can be site

specific and can appeal to players because of its uniqueness and ties to a special location, or can be suitable for any location.

DI 5. Creating mini-games to collect points/engage the player versus creating of a complex story. This affects the game design and types of audiences/players interest.

DI 6. Trusting all the users in the same way versus creating a validation model to assess users' credibility, considering the sounds classification. Regarding this latter issue, different models have been investigated in crowdsourcing contexts (i.e., [12]), such as computing the credibility value confronting a defined set of user's answers with a ground truth dataset or assigning the value on the basis of the other users' answers (e.g., exploiting a majority voting model).

Considering the pros and the cons of the different game approaches, and the innovative ideas presented, we developed two game concepts were selected as the more promising in addressing our objectives. The games selected revolved around a future dystopian scenario that could be fixed only with the help of the player. The background story for both the games was based on the following assumption: *a huge catastrophe happened in a far away past (in the year 2050). Human civilization survived. Now (in the year 3050) an agency in possession of time travel technology, focuses in recruiting agents in the past (our present, 2018) to collect samples of original species to restore nature to its former state. The player is part of the agency and he/she is needed to collect samples in the present (2018). A future based scientist guides the players in following the instruction of the game and helping them fix the future.* In this context, the two game scenarios (S) defined are: **S 1**. After the big disaster in 2050, the original nature was completely twisted, warped and original animals (except humans) and plants were not able to adapt and survive. Scientists in the year 3050 a.c. combine the creatures' samples, collected by the player in the past (in 2018, before the big disaster) to obtain several creatures able to survive in the present twisted, warped environments. **S 2**. The original nature was destroyed in 2050 and new creatures (mutants that combine several species together- see, for example, the mutant in the first paper prototyping wireframe in Fig. 2) were able to adapt and live in the twisted present (3050). A scientist from the future shows you (a present time inhabitant of the earth) mutants and asks you to find samples of the original species that compose the mutant, so he can separate the genes of the mutant and recreate the original ones, with the goal to repristinate the original healthy environment.

3.3 Focus Groups

Upon creating the scenarios of the two game concepts, we conducted 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 criticizing and refining the two gameplays. The session lasted one hour, including: the introduction of the context (biodiversity, sensors stations, Citizens Science); motivation behind the creation of a purposeful/persuasive game framework (issues we would like to address); presentation of the two game ideas

(concept, goal of the players, gameplay, and so on); discussion/brainstorming on the two game ideas. During the focus group, based on the experts' feedback, some game mechanics were refined and a few added to address the design issues, aimed at better meeting our objectives. After the focused group, the two games were developed into EP sessions in order to be tested and further refined.

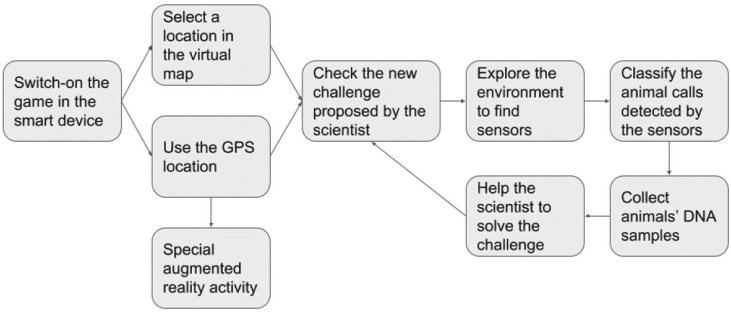

Fig. 1. Gameplay for both the games scenarios (S 1 and S 2).

4 The Resulting GWAP

As we refined the two scenarios and prepare them for testing as an EP, several design issues (DI) emerged from the concept ideation sessions.

DI 1. We hypothesized two game modalities: (i) location-based, where the user needs to be in the park; (ii) remote, with a virtual environment. In this way, we don't penalize users who live in locations without close parks with sensors installed, but we reward (with special contents) users who decide to play in a real park. In both the cases, we decided to exploit mobile devices.

DI 2. With the aim of engaging a large number of users, we opted to use the sensors only as a source of data. This means that, in our games, the sensors are just providers of data, they are not part of the game. This allows us to avoid several complications. Imagine, for example, a game where each sensor represents a virtual kingdom and the player needs to (virtually) "own/conquer" the sensors to be able to play. It is clear how different variables, that the player cannot control, come to play (e.g., the sensor stops working or it doesn't detect any animals calls for a long period).

DI 3. We decided to use historical data, to avoid problems related to the absence of detected animals in a specific period or area. Moreover, this also has the advantage to easily tracking changes on the biodiversity of a specific area, sensitizing the users. In fact, the player can travel in a specific time window in the past, visualizing the evolution (in term of quantity and differences over a specific period, such as a week, month or year) of the specific animals' detection, visualizing a timeline graph.

DI 4. The gameplay has been designed to include different breeds and species in the story, so as to avoid including constraints in the monitored calls and educate the users on biodiversity, in the whole meaning.

DI 5. We defined a game story that motivates the users in playing, moreover, to gain points, he/she needs to correctly classify the animals' calls and solve riddles.

DI 6. To assess the user's credibility, we embedded credibility tests inside the game flow, challenging the user in classifying sounds that have been already correctly labelled. In this way, we can assess the user's credibility and using this value to weight the player's input.

The gameplay (for both the games scenarios) would unfold as shown in Fig. 1. Accordingly, we used the MDA (Mechanics-Dynamics-Aesthetics) framework [7] to design the games in term of mechanisms, dynamics and aesthetics and created wireframes accordingly.

5 The Evaluation

5.1 Methodology

We evaluate our concept ideas through an experience prototyping (EP) session, using a mixed methods approach to collect data during and after the experience, performing observations, personal interviews (qualitative data) and asking participants to answer a questionnaire (quantitative and quantitative data). We only tested the location-based version for the games as the online one was still being designed.

We engaged 14 young-adults ranging from 21 to 30 (7 females and 7 males), 7 participants for each game scenario. We organized the EP session in the local University Biodiversity garden, rich in plants and animals, representing a perfect location for our game experience. In particular, we focused on the 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). The experience prototype was constructed as a mix of paper prototypes of the interfaces (see Figs. 2 and 3) and researcher's intervention as a Wizard of Oz style. Each session lasted an average time of 15 min. The researcher conducting the session acted as a storytelling voice (i.e., the scientist) assisting the user while playing. Two further researchers assisted in documenting the session and conducting interviews: one was taking pictures while the other was taking observation notes and performed the interviews, after each user's session.

To test both the gameplays, we defined two tasks to accomplish for both scenarios: (i) wandering in the park to find a certain animal, following the "future scientist character's" hints, and then, classifying its sound (sound samples of that animal were released on location); (ii) finding a specific plant that, in the game was able to attract a specific animals. These activities allow the player to collect animals' sounds samples and accomplish the game goal, accordingly with the game scenario (S 1 or S 2). We randomly assigned one scenario for

the experience prototype to each participant, and, in the end, we explained the mechanics of the other scenario.

At the end of each session, we interviewed the participants. We asked them seven questions, regarding the scope, the value, the mechanics, the touchpoints, 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. The questionnaire included 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.

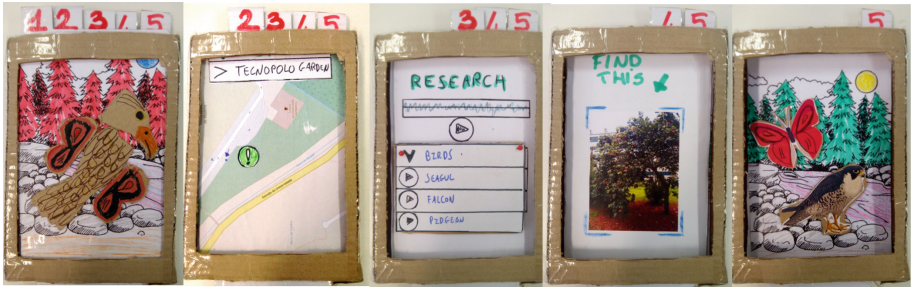

Fig. 2. The paper prototyping wireframes for the experience prototyping of S 2.

Fig. 3. Pictures captured during the experience prototype session.

5.2 Discussion

From the analysis of all the data collected (real-time observations and photographs, the brief interviews and the questionnaires) we can conclude that all

the participants have visibly enjoyed the experience prototyping session. This is documented in the pictures taken during the trial, as users' smiles, laughter and having fun expressions (as shown in Fig. 3). Moreover, the written accounts of the observations also support this data, for example, one observer noted: *The player looks amazed and she looks around with enthusiasm ... When she found the animal in the point of interest, she laughed and exclaimed "Awesome!"*. Users found the game interesting, easy to play and with a clear scope, independently from the scenario played. This was documented through the interviews, and questionnaires. Looking into the qualitative data, confirmation of users' enjoyment can be found in the following sentences. A user claimed: *"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, so I'm curious about the final application. I think that 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"*. So, overall, we can assume that the game captured quite a majority of not "hard-core game players" in engaging with the game.

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 hard game player (in fact, none of the users plays every day, and the majority of them play one per month or less). In this context, we take encouragement in having engaged non-core players in game activities as this is in line with our overall purpose of influencing biodiversity awareness and care for nature in a general population of young adults.

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

We also collected some players suggestion on how to improve the game. Suggestions range from adding a multiplayer option to making the story more dramatic and/or more challenging.

6 Conclusion and Future Work

This paper presents the design and a preliminary testing of two scenarios for a mobile game with a purpose (GWAP), aimed to: (i) motivate users in classifying animals sounds, collected with bioacoustic sensors; (ii) educate young users about biodiversity. To design the game, we performed an ideation and a concept refinement session with occasional gamers, digital media and engineers Master and Ph.D. students. Exploiting the MDA framework, we defined the

mechanics, dynamics, and aesthetics of the game, using wireframes to sketch the screen interactions. Finally, we evaluated the GWAPs with an experience prototyping session, engaging 14 young-adults, considering the primary target of the game. Results show the interest of the participants in playing and contributing to the data classification. Moreover, users being more informed about local fauna after the game session, they immediately realized the importance of the game for education and biodiversity awareness. This outcome represents a first confirmation of the possibility to use this GWAP for data classification and biodiversity awareness, addressing our objectives. We are now implementing the game for Android OS and we will evaluate it in a real-world study, using data from existing remote acoustic sensors present in different parks across Europe.

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