Confronting People's Fears about Bats: Combining Multi-modal and Environmentally Sensed Data to Promote Curiosity and Discovery

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ABSTRACT
Bats are often disliked and feared by people. How might we enable the general public to learn more about the true nature of these creatures, and even to like them? In this paper, we introduce *PlayBat*, a physical public display, which combines a multi-modal interface, a constrained narrative structure and real-time IoT environmentally sensed bat call data. The aim of our research is to investigate whether promoting curiosity and discovery through enabling people to explore real-life data, answer quiz-like questions and engage with a multi-modal interface, is effective at engaging people and confronting their fears. We report on the design process and implementation of *PlayBat*, and the findings from an in-the-wild study. We discuss how tapping into multiple senses can draw people in, evoke curiosity and even change their views.

Author Keywords
Tangible interface; Internet of Things (IoT); Curiosity; Fear confrontation; Physical visualisation; Playful technology

ACM Classification Keywords
H.5: Information interfaces and presentation (e.g., HCI): H.5.2. User Interfaces; H.5.m. Miscellaneous

INTRODUCTION
Many people have a dislike of certain animals, such as mice, spiders and bats, despite them being harmless species. They often see them as ugly, scary and frightening although they have rarely encountered them or know much about them. For example, a recent survey revealed 20% had an aversion towards bats [12]. Often, such fears are irrational or based on pre-conceived ideas [40,49], many of which stem from how the creatures are portrayed in films, e.g., seeing them as "blood-sucking evil vampires" [34]. How could technology be designed to enable the general public to learn more about the true nature of such creatures, overcome their fears and even to like them?

One approach has been to use campaign and marketing activities as a way of changing public opinion—for example, a number of countries have run a 'year of the bat' [62] portraying bats as fun and friendly, using illustrations in books, on mugs, car stickers, broadcasting new television and radio programs, etc. [40,59]. Another approach is to design interactive educational displays, that are placed in museums, galleries and information centres, intended to help the general public discover more about a species. Typically, multi-media apps have been developed that enable visitors to read text, look at images and watch videos by touching or clicking on an interface in order to learn more about a creature's habitats, diet, behaviour, etc. Virtual reality apps have also been developed that allow users to watch bats flying around them, such as Experience Bracken Cave 360 where over 15 million Mexican bats fly out of the cave [4].

With the advent of multi-modal interfaces and environmental sensing technologies, it is possible to go one step further by devising a more comprehensive experience, through offering up live recordings of the species and real data about their presence in a location. However, simply providing 'richer' or more novel information for people to hear or see may not be enough by itself. In fact, looking at masses of data in the form of visualisations, spectrograms or the like, might even overwhelm, or scare them more, reinforcing their fears. How can we design both engaging and informative experiences that can entice someone firstly to approach a novel display, secondly to spend time interacting with it, and thirdly learn something that makes them change how they think about bats? In particular, how can we design for both curiosity and confrontation? Our rationale is that curiosity can lead to confrontation which in turn can enable people to reflect about their irrational fears.

To this end, we designed a novel physical display intended to be experienced in public settings. *PlayBat* (see Figure 1) combines multi-modal interactions with real-time IoT (Internet of Things) bat activity data. Specifically, it uses an IoT wildlife data set that was being collected in a large urban park in London, where the activity of bats is being monitored

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Figure 1: *PlayBat*, a multi-modal device designed to spark curiosity and to confront people's preconceptions about bats.

for environmental purposes. This use of real-life data was intended to encourage users to imagine where the bats are and what they are doing in the vicinity they are visiting.

Our design rationale was that we could promote curiosity by presenting live bat call data in a novel interactive tangible form, combined with accompanying information presented in the form of a quiz. To sustain interest, we also included an overarching interactive narrative that users could immerse themselves in. The goal was to encourage both curiosity and discovery and in doing so instil a sense of intrigue, in this case about bats. An in-the-wild deployment was conducted in the urban park to evaluate how the general public approached and interacted with *PlayBat*. We discuss the findings from the study in terms of whether promoting curiosity, discovery and imagination, through enabling people to explore real-life data sets, answering quiz-like questions and engaging with a multi-modal interface, is effective at sparking interest and whether such interest could lead people who dislike bats to change their minds.

BACKGROUND

The design of educational interfaces has been varied—including the use of interactive installations [25], tabletops [24], novel tangible interfaces [1,51,60,61], wearables [43], or virtual reality [38], to name a few. Virtual reality (VR) has also been successfully used in phobia treatments, for example in reducing spider phobia [7,19], although further research and standardised reporting is needed to understand the phenomenon at scale [47]. Below, we review research on how tangible interfaces, physical visualisations and multi-modal interfaces have been designed for public use together with relevant theories about curiosity and confrontation.

Tangible interfaces

Tangible and playful interactions have been used as an alternative to more traditional multi-media displays for engaging the public to reflect on something, such as an opinion or state of affairs. Such interactions have been shown to spark discussions and socialising. For example, in the *Mood Squeezer* [18] study, passers-by were prompted to communicate their mood by "squeezing" a coloured ball. Aggregated data was then translated into an interactive floor showing the overall mood in the workplace. This simple interaction evoked reflective discussions on the organisation and served as a catalyst for informal conversations. In addition, Tangible user interfaces (TUIs) [28] have been successfully used to gather feedback from the wider public in various contexts—in one study, voting boxes were distributed around the city of Cambridge, UK. People were invited to answer simple questions about their local area which sparked discussions and reflection among citizens [35]. Other examples include *VoxBox*, a large physical device, designed to be used as a playful and attractive "questionnaire" at events [21], and *Sens-Us*, a set of physical boxes that transformed paper census forms into a physical and playful experience—both of which have been well received by participants [20]. These examples show how TUIs and familiar input/output mechanisms can engage people with reflective activities, such as giving their opinion, that may not conventionally be perceived as engaging.

Physicality has also been explored as a way to make it easier for non-expert users to understand and engage with large sets of data [39]. *Data physicalisation* uses physical artefacts to encode data through their geometry or material properties [30]. For example, data sculptures, augmented objects, and ambient displays have been suggested as an alternative to screen-based visualisations and have been shown to promote curiosity and engagement [39].

The importance of visualising IoT data

Visualising data, digitally or physically, has one main purpose: insight [44]. IoT networks can produce vast amounts of data but interpreting it can be a challenge, especially for non-expert users. Humans are generally good at spotting patterns and trends if data is represented visually [15] but while experts are primarily concerned with accuracy, flexibility and performance, for non-expert users to understand what the data means and how to make inferences, requires transforming it into appealing and easy-to-interpret representations [16,22,53]. Finding the right balance between the level of detail provided, the type of visual representation and interaction, and ease of interpretation is key to facilitating sense-making. If a visualisation does not match the user's skills and domain knowledge, then they can quickly lose interest [2,3]. Motivation to explore data is often tied to having an initial question that a user wants to answer. Information foraging theory [48] suggests that people with an information need follow an *information scent* - cues that help them assess whether they are on the right path to obtaining the desired information. Many people, however, do not always have a specific question in mind [8]. To make such unexpected encounters more engaging, incorporating visualisations into stories and narratives has been suggested as a way to overcoming the initial barrier. Stories can naturally lead people through a visualisation, suggesting initial questions worth exploring or directing users to formulate their own avenues of interest [8].

Multi-modal user interfaces

Multi-modal user interfaces take advantage of a richer spectrum of human capabilities compared to more traditional graphical user interfaces (GUIs). While GUIs are limited to screen-based interactions using keyboard/mouse or touch-based input, multi-modal interfaces seek to provide a more natural way of communication between people and computers by engaging multiple human senses both for input and output. In doing so it hopes to make technology more accessible to wider and non-specialist audiences. Research efforts have focused primarily on input mechanisms where the aim is to recognise and interpret various combinations of user input modes (visual, auditory, tactile) [29,46,58], e.g. combining speech and manual pointing to manipulate objects [6], speech and writing to interact with dynamic maps [45], or gestures, facial expressions and speech to recognise emotions [33]. Multi-modal output has included, for instance, combinations of tactile and auditory feedback to explore urban points of interest [32], visual, auditory and tactile output to enhance and facilitate children's play [23], or visual and haptic feedback to display large amounts of data in an ambient way [26]. Over fifteen years ago, Oviatt and Cohen predicted that multi-modal systems would at first enhance and later gradually replace GUIs in a number of applications [46]. This is beginning to happen, especially with the advent of smart mobile devices that recognise multiple modes of input including speech, handwriting, gestures and movement. Now that multi-modal technology is here a key question is how best to combine them to enrich the user experience. In our research, we are interested in how to combine audio, visual and tactile, as an alternative to a GUI-only interface, to trigger curiosity.

Curiosity

Curiosity is key to intrinsically motivated learning and is usually described in two dimensions: (1) *Sensory curiosity* requires attention-provoking changes in light, sound, tactile feedback, i.e. sensory modalities; (2) *Cognitive curiosity* builds on a premise that people are driven to form *"well-formed cognitive structures"* [37], i.e. structures of knowledge that are complete, consistent, and parsimonious. If people are confronted with a fact that their cognitive structures lack one or more of these qualities, they tend to seek a new balance by filling in the gaps [37,57]. Lee [36] proposed three factors that are key to curiosity and self-directed exploration: (1) *Sociability*—curiosity allows us to naturally learn from others and through that learning creating social bonds; (2) *Embodiment*—bodily exploration and physical affordances are key to curiosity as in our embodied nature we have learnt since early childhood to explore the world around us with our body and senses; and (3) *Playfulness*—can lower the fear of failure and support self-directed exploration. Relevant to playfulness is also Malone and Lepper's concept of a tool versus a toy—they define *toys* as *"objects that are used for their own sake with no external goal"* and tools as *"objects that are used as a means to achieve some external goal"* [37]. While tool needs to be easy to use and create as little friction as possible, toys should be challenging to master to intrinsically motivate a user. The core design principles to provoke curiosity can be summarised as: novelty, partial exposure, complexity, uncertainty, and conflict [36,41,57].

The aim of our research was to combine a tangible user interface with live sensed environmental data where the interaction is driven by a narrative framework. The rationale is to target both sensory and cognitive curiosity by designing a physical device that is aesthetically appealing, feels familiar, is slightly complex to master and which triggers reflection by quizzing users. Moreover, is it possible that adding live IoT data of this kind to the mix can provide a new approach to evoking curiosity by its novelty and in doing so confront people's fears?

THE SETTING AND LIVE BAT DATA COLLECTION

The Queen Elizabeth Olympic Park in London is undergoing a long-term regeneration programme. As part of this process, the local council and urban planners involved, have been investigating how to use sensing technologies and IoT to monitor various environmental aspects, including air and water quality. Recently, a number of bat monitors (called *Echo Boxes*) were deployed across the park to detect bat activity levels. The motivation for this new kind of nature monitoring is that bats are considered to be a good indicator species, reflecting the general health of the natural environment. A healthy bat population suggests a healthy biodiversity in the local area. The *Echo Boxes* "listen" to their surroundings using ultrasonic microphones and apply machine learning algorithms to automatically detect bat calls in the audio and identify the bat species. To achieve this, firstly, the captured audio is transformed into a spectrogram image (see Figure 2) where bat calls appear as 'hockey stick' like shapes. Secondly, deep machine learning algorithms scan through the spectrograms to find bat calls and then determine the species based on their shapes. These bat detection and species results are then uploaded and stored in the cloud.

While ecology experts are familiar with raw data and spectrograms, neither are suitable for presentation to the general public. For example, spectrograms show the amplitude of sounds across different frequencies over time and require training to understand and make inferences from.

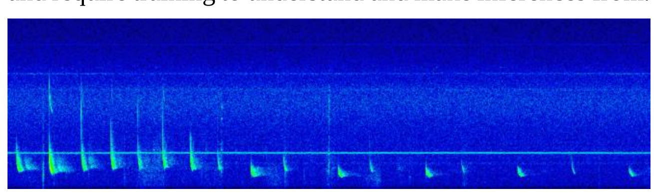

Figure 2. Spectrogram with 'hockey stick' shaped bat calls.

Instead, a different approach was chosen to represent the bat call data that would enable the general public to both obtain a bird's eye view of which bats were calling and how many bats there were in the park each night, along with the chance to be able to hear bat calls that are normally inaudible to the human ear.

METHODOLOGY

To understand more about people's negative perceptions towards bats and how these can be confronted, four subject-matter experts (SMEs) were initially interviewed. The following six perception-shift techniques were identified: (1) Share surprising facts that directly affect people, e.g. *'you wouldn't have tequila without bats'*; (2) Show visually appealing bat imagery (bat pups, fruit eating bats); (3) Point out the uniqueness of bats—the only flying mammal; (4) Remedy the myth about rabies—of 18 bat species living in the UK, rabies was found only in one, and overall, of over 15,000 tests of bats only 15 cases tested positively since 1986 (i.e. less than .001%) [5]; (5) Highlight the economic benefits of bats to people who are more rational (bats are important insect regulators and pollinators); and (6) Present bats as animals more similar to us than we think to people who are more intrinsically motivated and empathetic (bats typically live up to 20 years; they usually only have one baby, which they keep close and nurture). The SMEs also mentioned that it only took a few minutes to sway people's opinion once they were educated.

Based on these findings, we were encouraged to think about how to engage and 'sway' people through providing them with a multi-modal experience. A core design idea was to present live bat call data for people to both listen to and see as a way of enticing them to explore and learn more about bats. To transform the raw data into a multi-modal experience, a number of *Design Principles (DP)* were used. The main goal was to make the bat call data accessible to the general public. The principles used were a combination of seven relevant HCI guidelines on the design of interactive public installations, exploration and visual design:

DP 1: Provide unambiguous social and physical affordances
It has been recommended that indicating the purpose of a public display and offering unambiguous physical and social affordances can prevent social embarrassment [10].

DP 2: Make it fun and playful
Playfulness is considered important for promoting self-directed exploration [36].

DP 3: Evoke intrinsically motivated learning
It has been suggested that an optimal level of challenge is necessary to motivate people to engage in an educational activity and to spark curiosity [37,54].

DP 4: Keep it informative and trustworthy
Using content from relevant and well-established sources can create a sense of authority and expertise that can inspire trust by the user [13].

DP 5: Make it look attractive and novel
Making an interface visually appealing has been shown to attract attention, spark curiosity and motivate [36,42,50,54].

DP 6: Strive for consistency and coherence
An interface that is intuitive and consistent can be easily navigated while decreasing the likelihood of social embarrassment occurring [10].

DP 7: Support multi-modal output
When designing for different sensory modalities, e.g. haptic, visual and auditory, there need to be clear affordances as to what to do with each one or combination [17,20,21].

Designing the *PlayBat* multi-modal system

Various multi-modal content types were explored to include in the system for three senses: (1) Sight—bat data visualizations, videos, photos, information presented visually; (2) Hearing—bat sounds, videos; and (3) Touch—physical models of bats. These were combined with narratives that were developed with the goal of educating people and changing their perceptions about bats. The narratives were integrated with the IoT data and the different multi-modal content types to create a coherent experience. Inspiration was drawn from the field of *data stories* and *narrative visualisations* [8,27,55]. The idea was that the whole educational experience would be approached as one large narrative divided into smaller, relatively independent, story units. At the beginning of the main story, the educational content would be suppressed in order to entice and engage people through the use of interactive activities. Then gradually, other educational elements would be added.

A three-stage approach was used to design and develop the *PlayBat* multi-modal system. To begin, we focused on how best to visualize the live bat data, then the narrative and then the physical installation itself.

(i) Visualising the bat call data
The first stage of the design process involved working out how to represent the raw live data being collected by the IoT system in the park. From the bat call data collected, it was clear that the range of calls captured by the 15 separate sensors in one night could differ by an order of magnitude, with one of the sensors being particularly active (thousands of calls per night), while others would only capture dozens, hundreds or no calls. To visualise such scattered data, multiple ways of data physicalisation were explored, e.g. air flow, light, water, vibration, or mechanical movement (see for example [26]). A map of the park in which the sensors were placed was chosen as a base for the visualisation to provide context and the following criteria were applied to select the most promising concept: representation accuracy, potential to evoke intrinsic motivation to explore the data, visual appeal, and feasibility. The concept in which data is clustered and represented by different colours was selected (Figure 3). Although the colour representation does not offer the most accurate readings [14], it removes the physical limitations of displaying very variable data, and more importantly, such data abstraction presents a mild

interpretation challenge. Such a challenge could evoke intrinsic motivation to explore the data, especially when combined with appealing aesthetics of the colour representation. In addition, this solution is less expensive and easier to build than movement-based representations.

We made a decision not to interpret the data for the public but rather to use it in its raw form so as to let them devise their own ideas about what the changes in bat activity could be caused by, which could further promote curiosity and spark discussions. To enable the user to interact with the data a simple slider controller was added to select 'last night' and backwards for the last 10 days. The small LCD display above the slider shows a date and a cumulative number of all calls in a given day. Next, we describe how the narrative was designed.

(ii) Designing the interactive narrative

Key to devising the structure that would evoke curiosity and entice people to learn more were the SME interviews and literature review; these highlighted the need to remedy myths and misconceptions, raise awareness about the benefits of bats, communicate surprising facts, and introduce the benefits of conservation efforts. Relevant information was gathered from well-known and trustworthy sources, primarily bat conservation organisations, and combined with rich multi-media and multi-modal elements. The whole narrative was then framed with an overarching theme of listening to bats through the novel data stream. The language and tone of voice used throughout the story were conversational and friendly to further promote playfulness and to make the device feel more approachable and less educational. In a series of iterations, the main storyline was developed starting with a brief introduction to the project and the experience, and followed by a series of six story units.

Each story unit (SU) is introduced by a quiz question (Figure 4) which serves several purposes: (1) It challenges users and sparks curiosity; (2) If not answered correctly, it highlights effectively a gap in the user's knowledge and intrinsically motivates them to find the answer in the content that follows; and (3) It makes the experience internally consistent as all SUs are introduced by a quiz question. After a quiz question, there are between one to three content screens for each SU depending on how much relevant content needs to be covered. To further understand perceived enjoyment and the level of learning, five survey questions (SQ) were embedded into the story flow. At the beginning, users were asked to describe their initial attitude towards bats: *Before we start, could you please tell us honestly what is your opinion on bats? [I love them; I like them; I don't know; I dislike them; I hate them]*.

After an interaction, four further survey questions were posed to see whether a user's opinion had changed after using the device. These and the choice of answers were: (1) *Have you learnt something new about bats today? [Yes; No; Not sure]*; (2) *Has your opinion on bats changed a little bit after this experience? [Yes, I like them more; Yes, I like them less; No; I'm not sure]*; (3) *How enjoyable was your experience with this device? [Very enjoyable; Somewhat enjoyable; Neutral; Not very enjoyable; Not enjoyable at all]*; (4) *How easy or difficult was using this device? [Very easy; Somewhat easy; Somewhat difficult; Very difficult]*.

Below we present a description and rationale for the introduction and each story unit:

Introduction. To provide context and to entice people to engage with the device, the first screen introduces the device as a way to listen to bats *("We can now listen to bats in the park—and you can too")*, it also gives a hint on how to use the device and tells users that the experience will take approx. 5 minutes. Then, users are asked to gauge their initial opinion on bats through an embedded questionnaire and are shown information about the *Echo Boxes*.

Figure 3: Bat activity data visual representation. Different colours represent the intensity of bat calls.

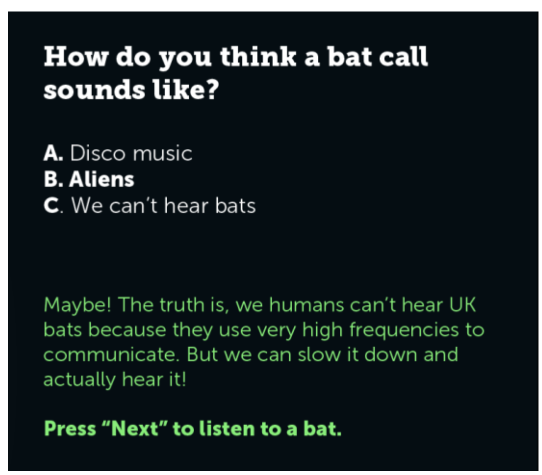

Figure 4: An example answer to a quiz question displayed at the beginning of Story Unit 1.

SU1: Listen to bats in the park. The first story unit allows users to listen to sounds of a common British bat, which were slowed down approximately 10 times to be audible to human hearing. A video of a relevant spectrogram is shown to evoke curiosity and to give more context to the sounds. Later a high-level explanation of the technology used in the park is explained. The assumption was that not many people would have heard a bat before and would thus find such opportunity intriguing. Having started with a playful experience, we hoped that users would be motivated to explore other story units.

SU2: See how bats move around the park. The second story unit encourages users to explore the interactive map with bat activity data (Figure 3). To further promote discussions around the data, several examples of what factors affect bat activity, in general, are shown.

SU3: Bust myths about bats. There are a number of misconceptions surrounding bats and here we select the ones that most contribute to the negative views according to the SMEs interviewed. These include: bats are blind; they get tangled into people's hair; they are ugly and scary; all bats carry rabies; they suck blood and attack humans. We dispelled all of these by providing relevant evidence accompanied by appealing bat imagery and later a video clip from a popular movie is included to show how we may be influenced by misconceptions presented in films.

SU4: The benefits of bats you didn't know about. To confront the view of bats as not being important, we present them as important pollinators and pest controllers. Some bat species pollinate a number of popular crops such as cocoa, bananas or agave, other species consume large amounts of insects. We also explain how echolocation works and we share some interesting facts about the life of bats to build empathy, as bats are in some ways similar to humans.

SU5: Meet the most common UK bat. To engage the touch modality through tactile learning, in this SU, we briefly describe the most common British bat (a common pipistrelle) and offer the opportunity to touch a life-size physical model, which was laser cut and adhered to the physical installation. Here we challenge the view of British bats as being large animals people should be afraid of—they are generally very small. Users can also listen to slowed-down sounds of a pipistrelle locating its prey and watch a related spectrogram to get a better understanding of how echolocation works in practice.

SU6: Two reasons why bats are endangered in London. Here, the conservation topic is touched upon as according to the UK bat survey [12], only 3 in 10 people know bats are legally protected. Bats are endangered in London due to development works and loss of habitat. In this SU, we also refer back to the new sensors as of a way to monitor bat populations which should help researchers better understand how human actions affect bats in London.

Next, we describe the process of designing the physical installation.

(iii) Designing the physical installation

The device was developed using three design iterations: (1) Low-fidelity paper prototype; (2) Medium-fidelity implementation prototype; and (3) High-fidelity integration prototype. The usability of each prototype was tested with 3 to 4 prospective users from the target audience recruited through convenience sampling.

We started by exploring the ways users could control the narrative flow. To select the most suitable input mechanism, the *Design Principles* were followed and five criteria applied: (1) User familiarity with the input mechanism—intuitiveness; (2) Playfulness; (3) 'Attractivity'; (4) Robustness; and (5) Feasibility. Illuminated 'arcade' buttons were selected as they represent a familiar and playful input mechanism with clear and unambiguous affordances. They can lead users effectively through the experience by lighting up actions which are enabled, and they are physically robust. The conceptual model of an arcade machine was also adopted in the design, as it supports both the button-based input and multi-modal output.

We designed PlayBat following the *Design Principles*, with an emphasis on sparking curiosity—our assumption was that by including strong physical affordances, such as headphones or arcade buttons, that are conventionally connected to play and casual activities, and by designing the device to look attractive, the participation threshold and fear of social of embarrassment would be lowered and passers-by would be intrigued to explore the device.

The final prototype, *PlayBat*, can be seen in Figure 1. It is comprised of five main components: (1) A set of 17 illuminated buttons and a volume potentiometer divided into four sections—story unit selection, flow control, quiz answers, audio/video controls; (2) A large 15.6" screen displaying text, quizzes, images and videos; (3) An LED-based interactive map of the bat activity in the park controlled by a physical slider and accompanied by a small LCD screen showing the date and a cumulative count of bat calls on a selected day; (4) Bat acrylic cut-outs, of which the largest is a life-size model of the most common British bat; (5) A pair of quality headphones which allow for non-distracted listening even in a noisier public space.

Additionally, a large sign was positioned at the top of the machine inviting passers-by to "Eavesdrop on bats in the park". The whole device is controlled by an Arduino Mega 2560 and an UpBoard running Processing on Windows 10.

Figure 5. Left—A popular bumper sticker from the 1980s [40]**; Right—The final pin badge design.**

To motivate users to finish the experience and answer the embedded survey questions, a reward was provided. With a limited budget and the intended target audience being families, pin badges were chosen (Figure 5). The intention behind the design of the badge was to create something aesthetically pleasing so that people would be intrigued to wear it. The design was inspired by a popular 1980s bumper sticker, which promoted bat conservation [40]. Badges were hidden in a box next to the device and users were only directed to it when they reached the final screen.

EVALUATION: IN-THE-WILD STUDY

An in-the-wild study was conducted to assess how the general public approached and engaged with *PlayBat*. The system was deployed for 3 days in a café located in the London park where the bat sensors were already deployed. Three evaluation methods were used to assess user behaviour: (1) Passive observation; (2) Intercept interviews (n = 28); and (3) Data logging of the device usage. Participants were not actively recruited, and only modest signage informing about the research was placed next to the café entrance. Verbal consent was obtained for each intercept interview and a summary of an interview was written down immediately after it ended. Interactions and interviews were not videotaped as it was a public setting. Observation notes and interview transcripts were analysed in NVivo 11 following the thematic analysis methodology [9] using grounded theory methods of open coding and memoing [11]. We also did not ask users directly after using *PlayBat* as to whether they had learnt something new. This approach was taken in order to prevent people from simply saying they had learnt something so as not to embarrass themselves or to satisfy the researcher. Instead, we used the log data from the survey questions at the end of the interaction. The device recorded a time-stamped log of every button press, slider movement and every screen displayed.

The device was installed on a dining table approximately three meters from the main entrance. Each day, the most recent figures from the live bat data stream were manually updated in the Arduino program and related figures changed in the dedicated quiz question.

FINDINGS

PlayBat was used by 232 people in total during the three days in 127 interactions (an interaction is defined as the time from someone approaching the *PlayBat* to leaving it). Visitors seemed engaged and used all the multi-modal features. In 46% of interactions, a single individual used the device; in 54% of interactions, *PlayBat* was used by a group of people. Groups ranged in size from 2 to 5 people (M = 2.5, SD = 0.8). The device was used mostly by young families (35% interactions), followed by children by themselves (32%), adults (22%) and teenagers (11%). In total, the device was available to use for nearly 20 hours—during this period direct interactions accounted for 8 hours and 33 minutes which means that the device was in use for 45% of the deployment time.

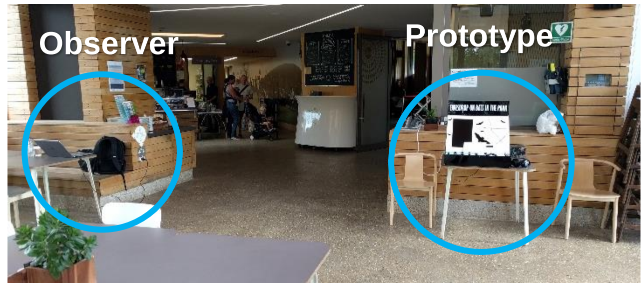

Figure 6. The in-the-wild study setup.

A number of young children repeatedly or randomly pressed the buttons. These interactions were excluded from our analysis (identified using time-stamped observation notes) ending up with a total of 158 sessions analysed (a session refers to the logged time recorded, from pressing the start button to either restarting the device or to finishing the experience). Of these sessions, users in 62 of them (39%) reached the final screen to unlock a surprise. Users visited all six story units in 33 sessions (21%). Session durations ranged from 6 seconds to 15 minutes (MEAN = 173s, SD = 169s). There were 28 sessions lasting between 3-5 minutes, 23 sessions lasting between 5-10 minutes, and 4 sessions lasting longer than 10 minutes. Survey data from 89 sessions were collected on the last day (technical problems prevented them from being analysed for the first 2). Of those, 28 surveys were completed in full, i.e. all five survey questions were submitted. Below, we present the detailed findings in terms of what interactions took place during a session.

Data analysis

Overall, most of the 28 people who were interviewed after using *PlayBat* said how engaged and focused they were. The quizzes were also mentioned as highlighting knowledge gaps, making them curious to know what the correct answers were. They also mentioned how they enjoyed discovering corrected myths and misconceptions: "*The misconception section was really interesting actually.... You grow up with those things being told to you and you don't realise they may not be true, like that they're blind or they tangle into hair,"* (I119). Another person noted: *"I learnt so much. I didn't know about the rabies, they just tell you all the time that all bats carry rabies, and I didn't know they were this small! In movies, they are always like this big [spreads her arms about 70cm] and they are really tiny,"* (I019). Some people shared specific data they learnt: *"I learnt that there are 18 kinds and they are protected since 1981 [smiling],"* (I007).

Hence, the narrative approach adopted with the fun quizzes was successful at provoking curiosity. There was also some change in the final questions: suggesting that for a few people this led to confrontation about their fears and prejudices that made them reflect and possibly rethink them. Of 28 completed surveys, eight respondents were initially apathetic or negative towards bats. Figure 7 shows that over half of the participants said that they love or like bats. This is in contrast to earlier survey findings showing significantly less. However, despite more people saying they liked them to begin with, 71% stated they liked bats more (Fig. 8) after interacting with PlayBat. Additionally, 93% (26 users), who finished the survey, stated they had learnt something new.

Many people were surprised that it was possible to make the bat sounds audible to humans: *"I didn't know we can slow the bat sounds down, so that was the first time I could hear bats, that was amazing,"* (I034). One participant shared his revelation about bats being present in the park: *"You don't realise that there would be that many animals in the park, especially when it's kind of artificially constructed here, so yeah that was quite eye-opening, actually,"* (I045). Even to people who were more familiar with bats, the experience offered something new to learn: *"I thought I knew something, you know, but clearly, I was wrong. I didn't know they were pollinators,"* (I070). Many people also pointed at the photos of the bats they saw on the display and smiled suggesting that their views of bats as being "ugly" were being positively challenged.

One participant summarised the multi-modal experience in the following way: *"We really learnt a lot about bats, hearing them and touching the models, then having the quizzes, it was just really excellent […] I actually didn't like bats too much but now I quite like them,"* (I023). The bat cut-outs also engaged people and made them learn. Many children, as well as adults, touched the cut-outs, especially

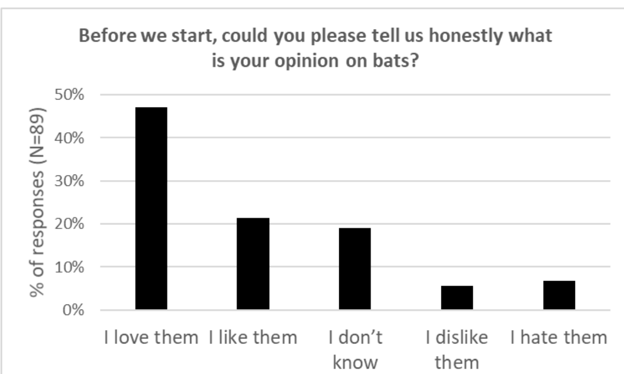

Figure 7. Embedded survey question results—user opinions about bats before using *PlayBat*.

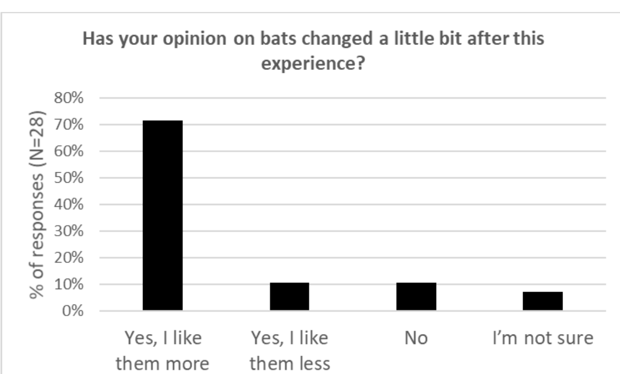

Figure 8. Embedded survey question results—user opinions about bats after using *PlayBat*.

the largest one (the life-size model)—sometimes they compared its wingspan to the size of their hand, and in several cases, parents showed it to their children saying: *"Look, that's how big the bat really is,"* (I037).

Below we describe the findings in terms of a set of themes related to the multi-modal design principles used that helped us to analyse further the user experience in terms of curiosity and confrontation. These were: *The lure of multi-modal design*; *How curiosity sparks discussions*; *Interactivity, playfulness and engagement*; *Multi-modality and collaboration*; *The role of physical affordances and interaction*; and *Context and the quality of interaction*.

The lure of multi-modal design

Most people passing by *PlayBat* noticed it immediately, often pointing at it and passionately exclaiming: *"Oh, I love that!"* (I069), *"Bats, oh wow!"* (I103), *"Wow, that's nice,"* (I111). Neither adults nor children hesitated to interact with it. After catching sight of it, they instantly approached it, changing their immediate plans. Children were more proactive in this regard and often drew their parents in. A participant (I119) mentioned about his son: *"He got attracted by it right away, I mean, it looks amazing."* Several families took pictures of their children posing with the device. A number of people (12%) even queued to use the device, waiting nearby, watching the current users and then approaching *PlayBat* immediately as it became available. Some people (predominantly adults) showed interest in the device, looked at it closely but then walked away. When asked why they decided not to interact, the most common answer was that it required a time commitment: *"Just busy doing other things, it looks really interesting but I don't have time for it,"* (man, 60+); *"I'm not sure I have time for it,"* (man, 30-40).

How curiosity sparks discussions

Several design elements appeared successful at sparking curiosity and consequent discussions. The most prominent in this sense was the interactive map featuring the bat call data. Most people pointed at the map and used the slider repeatedly to discover patterns. If they were in a group, they then started discussing together what could be causing the changes in bat activity, for example: *"Ah that's really interesting, they [the bats] seem to be around the café quite a lot, that probably makes sense because it's much quieter here [compared to the rest of the park where there are a stadium and other attractions]"* (I037). Sometimes, parents would guide their children to understanding the map: *"Oh, look at last night, that seems busy here,"* (I075). Showing where the users currently were in relation to the map helped to contextualise the experience. For example, one person said: *"I tried to understand where there are most of the bats and how they move around, and then I thought 'where are we actually?' and I saw it on the map*," (I006). Also, displaying the latest data from previous nights was perceived positively: *"What's also great is that the data is real-time, like, being able to see what happened last night and the* *nights before, that's just amazing"* (I023). However, one person mentioned that the visual representation did not help him to understand the changes represented in bat calls: *"You understand the colours represent the number of calls but it's not very easy to follow, to really understand it."* (I057). He did not want to have a guess himself as to why there was more or less bats in a location whereas many of the other users did.

Another feature that made people curious were the quizzes introducing each story unit. People often spent a few seconds thinking before answering the questions and cheered or "fist pumped" when they answered correctly. If they answered incorrectly, they became curious and motivated to search for an explanation in the content that followed. It was also apparent that participants got curious when they reached the final screen and were prompted to open the box next to the device to discover a "little surprise". Almost everyone who opened the box then smiled and some children shouted for joy: *"Oh! 'I love bats' badge!"* (I051), *"Oh my god, it's a bat badge!"* (I079). For one participant, opening the box evoked anxiety: *"At first, I was a bit afraid to open the box [smiling], I didn't know if there would be a dead bat or something [laughing],"* (I003). Many children, as well as adults (17%), put the badge on their clothes instantly.

Interactivity, playfulness and engagement

People often smiled or laughed when interacting with the controllers of the *PlayBat* device. Many put the headphones on to listen to the bat sounds: *"The sounds were very cool—I think it was a pipistrelle the sound of it, it was quite high and really nice"* (I021). There were many cases where parents would guide the experience to find the bat sounds and then get their children to listen to it: *"Can you hear the bat? It's interesting, isn't it?"* (I071). Children also commented to their parents about the sounds: *"Dad, you can hear bat noises on this, it's really cool,"* (I098). Two people mentioned they would want to hear more species.

A few people were curious only to hear what a bat sounded like. They pressed the *Listen to bats* button straight away, then they asked their children if they could hear something. One person wanted to know what a bat sounded like and then left: "*I just thought it would be too much effort to get to something interactive. I just wanted instant gratification, just to hear the bat,*" (I072). However, most people explored the interface, pressing the buttons to go through the story units as designed.

Multi-modality and collaboration

The device enabled groups to collaborate when interacting with the *PlayBat* in a number of ways. This resulted in discussions, reading aloud and commenting on what they were seeing, hearing or touching. Most commonly, people shared the control panel while reading what was on the screen aloud to their partner, children or the rest of the group. Parents often guided the experience for their children but let them answer quiz questions and press buttons. Parents were not the only guides, however. Sometimes a child who had already used the device would bring parents or other children and proudly show them how to use it.

Groups of people almost always took turns in using the headphones. This created many subtle cooperative interactions, for example, a boy would take the headphones: *"Let me go first"*, while a girl would be asking him: *"Can you hear bats?"* (I049). Sometimes, however, it made the person who could not wear the headphones unengaged or restless, waiting for their turn. Some couples even tried sharing the headphones.

The role of physical affordances and interaction

It was clear from the observations that the users enjoyed touching aspects of *PlayBat* and seeing things change when moving the slider controller. Young children (under 6 years), who could not read the text on the screen, still had an engaging experience; as evidenced by them touching the bat cut-outs, randomly pressing buttons, listening to the bats, moving the slider and rotating the volume knob. Parents would help explain or read aloud what they were seeing on the screen—in so doing it became very much a joint engagement. The bat cut-outs were also popular; challenging people's views on how big British bats really are. This shows that a very simple and cheap tangible interaction can convey important information.

Context and the quality of interaction

Several external factors made users stop using the device before they had completed all the narrative units. In 13% cases, people went to get food or drinks from the café. Parents sometimes left their children at the device while they were getting food but called them when it was ready, summoning them to join them at a table. On a few occasions, parents left the café, asking their children to join them outside. Such abrupt disruptions were often negatively received by the children—they refused to leave the device and their parents had to call them repeatedly (10%). Some children, as well as adults, used the device repeatedly (18%). This was either to experience it again or to continue where they had left off.

DISCUSSION

As can be seen from the largely positive feedback and observations of *PlayBat* being used in the park, the device was successful at engaging the public. We were interested in whether by exploring the real-life bat data and answering quiz-like questions, visitors were able to learn more about bats that could also change their views about bats. Most people followed the narrative and completed all the quizzes while trying out the other multi-modal aspects (e.g. touching the laser-cut bat model, listening to the bat calls and interacting with the bat data). This suggests having a varied interface and different activities is able to sustain user interest throughout—something that can be difficult to achieve in museums where dwell time at each exhibit can be considerably less [25,56]. Having a constrained narrative structure that was easy to follow—a set of sequenced pages and quizzes together with discovery-based activities that the visitor could readily switch to and back from—also enabled the visitors to determine and be in control of their own experience, and in doing so make connections between what they were hearing, seeing, touching and exploring. Moreover, the bat IoT data appeared to become part of the larger narrative—by being embedded in the interactions. People spent considerable time interacting with the bat call data interspersed with following and answering the quizzes in the various story units. Hence, the multimodal interface was also able to trigger and sustain curiosity as evidenced by the comments made, return visits and conversations among groups of visitors, and the length of time spent looking at the data visualisation.

Our decision to focus on bats was motivated by previous surveys showing how many people are fearful of them. However, we were surprised to find that many of the visitors who came to the PlayBat installation said they liked and even loved bats. This bias in our visitor sample may have been because those who interacted with the display were attracted by the bats embedded in the installation, which could be seen from a distance. But this is likely to be the case for all public installations when it is entirely up to the visitor to decide whether to approach an exhibit. One way to attract a more diverse audience is when school parties and other groups are invited to all have a go (cf. [31]). The data that was collected by *PlayBat* indicated that a large number of users had slightly or significantly changed their opinions—from negative to positive and from positive to even more positive. This in itself is very promising as it suggests that having both 'hands-on' and 'ears-on' experiences about a certain topic or issue can facilitate reflection on people's current level of knowledge and enhance or confront their views. Future research could explore when there is a greater change in perception from negative to positive—be it for bats, spiders, snakes or even more generally, other topics where it is known people have strong negative dislikes (e.g. eating green vegetables).

Interacting with a simple 'bird's eye' map visualisation of the bat call data, that visitors learnt was actually collected in the park, was also considered to be an effective way of facilitating curiosity. After using *PlayBat*, they could then return to the park and look out for the *Echo Box* sensing boxes that were visible on the lamp posts they were attached to. This form of indoor-outdoor connection also enables initial interest in what is being presented on a display to be extended further outside rather than stopping once they had moved on from the installation (cf. [52]). This suggests that there might be more opportunities for other public STEM learning to be brought alive; such as citizen science, information centres in national parks and museum settings, where sensed data about some aspect of the environment is being increasingly collected. However, we suggest that simply presenting the data in the form of 'scientific' visualisations may make it too difficult for non-experts to make sense of. That is not to say that these kinds of 'expert' representations should not be presented but that they should sit behind or besides more accessible and interactive visualisations.

CONCLUSION

PlayBat was designed as a new form of multi-modal interface intended to evoke curiosity that could lead to challenging people's perceptions of a generally disliked species—bats. A combination of provocative quizzes and playful interactions was able to sustain people's curiosity and interest long enough to convey information that could challenge and even change their opinions. Our approach shows that the combination of a tangible interface, physical visualisation, familiar input mechanism and multi-modal output and the opportunity to explore actual bat call data collected in the park where the installation was located, can intrigue and engage people across a range of ages. In doing so, we were able to create an indoor-outdoor connection which allows visitors to relate the data they have seen in an installation with what they can see outside. Our findings also suggest that presenting this kind of Big Data in an accessible and playful physical form can promote much exploration of it. In sum, *PlayBat* has shown how it is possible to combine a novel multi-modal interface with real-time sensed data about a species, previously not available, to create a new kind of informal learning experience that can make people reflect and even confront their irrational fears.

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