Nature Soundscapes: An Audio Augmented Reality Experience

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ABSTRACT

Augmented Reality (AR) has developed to be a popular and exciting technology domain, gaining notable public interest from 2009 to the present day. AR applications have traditionally focused upon paradigms that are visually led. In this paper, we document an Audio Augmented Reality (AAR) project, which considers soundscapes and how they might be transformed via the application of music and sound technologies. This work is concerned with the augmentation of nature soundscapes and explores how this may be used to enhance public understanding of the natural world. At present, we are concerned with the augmentation of spaces with biophony. Two examples of acoustic augmented reality are described: an initial pilot study to investigate the feasibility of the approach and an installation at the Timber International Forest Festival 2019. A technical description of each is provided alongside our own reflection and participant feedback, garnered from a soundwalk inspired approach to evaluation by audiences at the festival.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Sound-based input / output**; Auditory feedback; Activity centered design.

KEYWORDS

Augmented reality, soundscapes, nature

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1 INTRODUCTION

Augmented Reality (AR) is a set of technologies and approaches that facilitate the overlaying of artificial, often digital, information, with the real world in which a user finds themselves. A simple visual example is a smartphone app that uses the built-in camera. When pointed at an object, such as a car, the app might give the ability to overlay, in real-time, information relating to that car, such as the year of manufacture, engine size, and so on. Whilst it can make use of some of the same technologies as Virtual Reality (VR), it differs because it is 'closer' to the real environment, whereas in VR the user finds themselves detached, visually and aurally, from the world around them. AR has applications in a wide range of domains, notably those relating to education, heritage, navigation, games, and any activity that involves considering the physical environment that surrounds the user [46].

Audio Augmented Reality (AAR) is an instance of AR, whereby experiences and actions in the real world are accompanied by additional layers of sound. The use of audio layers can be considered analogous to the visual example described previously and can similarly provide additional information and affordances to a user or audience. Use of audio augmentation can be both entertaining and engaging [7]. Furthermore, the use of sound means that cognitive and physical constraints encountered when display devices can be overcome [47]. Additionally, in our current work relating to the natural environment, it is not always possible to detect the presence of the wildlife that occupies the space, particularly visually due to the distances involved and the natural camouflage of the wildlife.

Our aim was to produce a nature soundscapes AAR suitable for a broad range of audiences that would be informative, engaging, a tool to address the disconnect many people have from nature, and to raise awareness of species decline. Using audio augmentation to communicate this information means that an experience can be produced with high-levels of realism and that frees up the other senses to engage with an instructor who can facilitate an interactive learning experience. As part of this investigation, we tried out a range of hardware configurations to implement this experience.

In the next section of this paper we provide a background to soundscapes and augmented reality before discussing a representative range of the existing work in AAR and how this particular specialism might yield benefits to improve people's awareness, levels of knowledge, and understanding about the natural world. Subsequently, we outline our vision and designs for the experience we produced and describe testing it in two real-world environments. The first of these was to determine its feasibility in an outdoor scenario, whilst the second is a refined implementation and reports upon the feedback received from audience members at a large outdoor festival in the UK. Finally, we provide an overall reflection upon our AAR experiences so far and discuss plans for future work.

2 BACKGROUND

2.1 Soundscapes and AAR

The seminal work relating to the study of soundscapes was produced by R. Murray Schafer and describes a soundscape as being a sonic product of the physical environment and its inhabitants [41]. Like the visual equivalent of a landscape photograph, the soundscape depicts an environment and describes its characteristics, depending upon what can be heard. For example, when listening to a

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soundscape recording, a listener may hear aspects of the weather, the movement of plants and trees, vocalisations of animal inhabitants, birds, and so forth. This can be extended to consider that the timbral qualities of the recording may also give an indication as to the location of sound sources and the acoustic qualities of the space, indicating, for example, the density of plant life, distance from various animals and birds, and so on.

Soundscapes are an intertwined mixture of their context, the physical environment, the sound sources, and the listener's perception, knowledge and experiences [42]. The perception of a soundscape is formed by the listener, their expectations, emotions, and cognitive associations triggered during exposure to the sounds heard in a location [6]. Two types of soundscape listening can be considered: *attentive* and *holistic* [6]. The former describes listening that is attention-oriented, such as might be experienced when trying to hear a particular bird in the environment. In contrast, holistic listening is a more passive experience, where one hears the ambient sound of the environment but is not attending to a particular source or any other form of analytical listening.

Acoustic ecology is concerned with examining the relationship between humans and their environment through the medium of sound [45]. Soundscapes alter people's experiences of environments, increasing the perception of tranquillity and enhancing their visual aesthetic quality. This effect was especially potent when the soundscape presented included inclusion of natural sounds, such as birds and crickets [38].

Eckel [9] describes an example of a system that makes use of sound to augment the environment. In the LISTEN project users wear wireless headphones and sound is presented in-ear through binaural renderings. The proposal describes the use of such approaches in static contexts, specifically museums, although there is no reason why semi-static (where objects or their characteristics move or modulate their states, for example) and fully dynamic spaces ought to be excluded. Eckel highlights some important aspects of AAR, notably that: 1) they can be tailored to each user; 2) they are non-linear; 3) they should make use of spatial reproduction; 4) they can be used to either enhance or augment the surrounding environment; and 5) they should track user engagement to avoid unwanted repetition. In the case of the AAR experiences that are being designed in our own work, aspects 1 to 4 from Eckel directly apply, whilst point 5 is indirectly relevant since repetition can be desirable for education purposes, although variation may be beneficial to avoid perception of the sounds as artificial.

Wakkery et al. [47] describe another approach to deploying AAR in a museum. A three-level soundscape model is adopted, each contributing to the overall experience, but with increasing levels of detail and learning content, whilst the level of attachment from the physical environment around the user, it might be argued, decreases. The three levels are: a movement-related dynamic soundscape, akin to what might be considered a *sound bed* or *room tone* in sound design terms; the second involves audio attached to objects in the exhibition and facilitates user interactions; and the third, which provides specific learning intentions.

Sikora et al. [42] support the adoption of AAR as a tool to change the naturally occurring mixture of biophony, anthrophony, and geophony in an environment. Their research documents an AAR experience situated in an outdoor space, specifically that of an archaeological site. Their approach shows the feasibility and value of taking users on a historical journey or recreation, using audio as a key driver. Technologically, the approach makes use of a smartphone and headphones, using binaural rendering, for audio reproduction. The authors used an experimental approach, with two groups of participants experiencing the archaeological site with and without the AAR. Their results showed statistically significant findings, from subjective and objective measures of emotional response, that the use of AAR technology contributed to a heightened, more stimulating user experience.

Many of the related AAR approaches have so far been understandably concerned with application in settings related to tourism, culture and heritage [7, 14, 42, 47]. These settings are ones where the AAR system provides additional information about objects in, at some point in time, the environment surrounding the user.

Applying AAR principles, Rovithis et al. [40] presented an audio game and explored the ways that gestural interactions could be mixed with spatial audio information. Whilst the application area is quite different to the work being proposed here, it is notable that the authors discovered that qualities of the audio presented, such as the fidelity and sound design contributed to a positive user experience. It is argued that if one is designing a soundscape, and in the case of our own work when augmenting a soundscape, then the design process should take into account the expectation of the listener(s), possess realism, and direct attention in a positive manner [6].

2.2 The Natural World and Wildlife Conservation

Sound forms an important part of the natural world, therefore understanding how humans respond to natural soundscapes may offer an important approach in the conservation toolbox. This research is timely for a number of reasons, as around the world biodiversity is in crisis. In a UK context, we are, as the former Secretary of State, Michael Gove, said in July 2019, *"...among the most nature-depleted nations in the world"*. According to the Mammal Society, 1 in 5 British mammals face extinction in next decade [22] and the State of Nature Report (2019) [13] indicates that 1 in 10 of the UK's wildlife species are threatened with extinction, and that the abundance of all wildlife has also fallen, with 1 in 6 animals, birds, fish and plants having been lost. On a global scale we are in a severe biodiversity crisis (the 6th mass extinction, e.g., [24]). The Global Planet Index [12] shows a decline of 60% between 1970 and 2014 of population abundance for 4005 species. The UN's Sustainable Development (2015) include *"urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and by 2020 to protect and prevent the extinction of threatened species"*.

As a global society, we are also facing unprecedented challenges from human-generated climate change [27, 35, 39] and associated loss in ecosystem services. Recently, there is growing evidence that the outbreak of Covid-19 and similar zoonoses have their roots at least in part in poor land management and conservation practice [37]. Global nature depletion also threatens the well-being of people in other ways. University College London's Millennium Cohort Study indicates that a quarter of girls (24%) and one in 10 boys (9%) declared depressive symptoms at age 14 [31], and approximately

1 in 4 people in the UK will experience a mental health problem each year [26] and in England, 1 in 6 people report experiencing a common mental health problem (such as anxiety and depression) in any given week [25]. A systematic review of how accessibility, exposure to and engagement with nature affects the mental health of children and teenagers identified statistically significant positive relationships between nature and mental health outcomes in around half of the reviewed papers [44]. There are therefore important drivers to re-examine how we interact with the natural world, and sound has a potentially important part to play in this process.

2.3 Education Potential of AAR Experiences

Amongst the extensive array of sounds that we experience in our daily lives are those offered by the natural world. Blackbirds, sparrows, pheasants, robins all vie for the attention of others of their species and some even attract our ear. We may all recognise the distinctive call of the cuckoo and those who live in the countryside may be familiar with the *"pee-wit"* call of the Northern Lapwing in Spring, and in Autumn the bellowing of the red deer stag. Those in the city may even be familiar with the night-time barks and screams of the urban fox. However, many of these sounds, for instance the dog-like barking noises of the roe deer when startled or the 'haunting' call of the loon, go under recognised by most human listeners. The 2017 RSPB "Birdwatch" Survey found that of 2,000 adults, half couldn't by sight recognise a house sparrow and a quarter didn't know a blue tit or a starling, let alone have any idea what they sound like.

AAR provides an opportunity to address this, enhance an individual's perception of their environment and thereby learn through their experience. Beard and Wilson [3] referring to the works of Gibson, Ivancevich and Donnelly [11] and Massaro and Cowan [21] describe the process of perception and experiential learning, where through use of a range of senses an individual becomes aware of a stimulus, either consciously or subconsciously. The individual then begins the sense making process where the stimulus is 'filtered' and interpreted, based on amongst other things, previous knowledge, experience and emotions. The final stage in this model recognizes the cognitive, behavourial and affective responses [5].

Providing augmentation of nature soundscapes will transform the participants' sensory perception of and interaction with the real world [15] and Prince [33] advocates that *"...pedagogical approaches that stimulate sensory awareness, by their very nature encourage and stimulate curiosity, exploration [and] inquiry....".* Likewise, O'Brien and Murray [30] emphasize the potential sensory and intellectual benefits to be gained when engaging children with the environment. Through the use of AAR a deeper understanding of the environment can be achieved by providing a novel stimulus facilitating a sensory connection with an individual's surroundings. By facilitating an experience using AAR, whereby people become more attentive and critical listeners, we can identify and explore our environment in a richer way and cognitive, behavourial and affective response can change. Thomas [43] suggests that *"the more bird sounds you learn, the more birds you will notice..."* and by beginning to question, what was that noise and then to attribute it to particular animal or bird we may move on to develop a concern for it [19]. By helping develop 'sonological competence' [41], the use of AAR offers an alternative to 'eye culture' [4] whereby sight is privileged over other senses [20]. So, if AAR can help put a name to a sound, then it may help to address Robert Macfarlane's [19] concerns: *"We've got more than 50% of species in decline. And names, good names, well used can help us see and they can help us care. We find it hard to love what we cannot give a name to. And what we do not love we will not save."*

Through the use of AAR we hope to stimulate interest in the environment, enhance the participants' transfer of knowledge [32] and strengthen retention of newly learned information.

3 DESIGNING THE NATURE SOUNDSCAPES

3.1 Overall Vision and Aim

A taxonomy of AAR was recently proposed, represented by six broad categories [16]. This allows us to better articulate the functionality of our own AAR system. Our approach has the potential, and our vision is that it should be able, to fulfil four of those AAR modes, namely: *"Enchanting silent physical objects with digital sound"*; *"Deliberate blending of acoustic and digital sound"*; *"Digital sound-objects placed in real 3D space"*; and *"Overlay of extra audio information onto the real world"*. However, in this article, we are concerned with the testing of our AAR system that is limited to the categories of *"Deliberate blending of acoustic and digital sound"* and *"Digital sound-objects placed in real 3D space"*.

Our intention was to develop AAR experiences that would interact and mix with the natural soundscape around the user, rather than replace it. There is an emphasis upon the role of technology as being in place to facilitate and support the encounters that the users have with a space, perhaps best stated by Wakkery et al. [47] with respect to using AAR in a museum setting: *"...it amplifies and strengthens the visitor's ability to explore, learn from and construct the meaning of exhibitions"*.

At a high-level, we wanted to create a nature soundscape experience that would facilitate many types of content in an outdoors environment and in several configurations. These requirements were formed through the knowledge and skills of the research team, including ecological activity provider Albion Outdoors. By doing so, there would be multiple opportunities to author a variety of soundscape experiences by sourcing appropriate audio sets, deploying them in a software environment, and accompanying them with a suitable narrative.

In terms of content, it was decided that the experience should facilitate a journey through time broadly divided into segments of past, present, and future. This would permit the sounds of lost wildlife to be heard alongside other species that are in danger of extinction. The purpose of this was to highlight the concept of species loss. In the present time segment, the AAR experience would allow species to be heard more clearly than possible in normal life, perhaps because of the time of day or geographic location, but also since some sounds are generally inaudible to the human ear. Finally, the future segment of would grant the opportunity to make predictions about how the natural environment could sound. This was a unique affordance as it meant that alternate futures could be presented, permitting soundscapes of increased industrialisation and species decline, or how re-wilding and species reintroduction could be used to foster the introduction of new or lost species.

For delivery, portability was identified as an extremely useful characteristic so that an AAR experience, or set of experiences, could be configured in multiple ways. In the main, the foreseen configurations would support situations where the audience would either be static or in motion. For static experiences, it was considered that the audience might be sat around a campfire or stood in a clearing. In this scenario, the sound would be able to surround the participants. The alternate scenario would be where the participants were moving through an environment, such as when following a nature trail. In this setting, the sounds would be likely to come from a fixed position and be used to guide or direct the participants.

A decision had to be taken about whether to develop a system and set of experiences oriented use of either headphones or speakers. Headphones are common in AAR, but can obscure the soundscape around the listener. There are notable challenges in the use of headphones, especially when the aim is to present spatialised 3D audio. These relate to the requirements of being able to determine a user's position and orientation and to translate audio events into a successful binaural experience by applying Head-Related Transfer Functions (Kaghat and Cubaud, 2019; Sikora et al. 2018). Ultimately, it was decided to use loudspeaker reproduction, since most of the AAR experiences to be devised would be deployed in controlled installations and so the hardware would remain static during each experience. This also reduces the amount of time required to develop the experience. However, spatial reproduction using headphones has not been ruled out in future and could be facilitated by use of lightweight, open models, for instance.

It was apparent that a multi-channel audio system would be required to run the experience, making use of multiple physical speakers. When considering the software to be used, two options available were: a traditional Digital Audio Workstation (DAW) or the authoring of content with game engines and associated middleware [7, 14]. The former would be easier to configure and operate for someone with limited audio experience but would be constrained to linear, pre-scripted experiences, unless an operator was available. The benefit of using game audio approach is that it would provide greater opportunity for interactivity and variation in the timbre and level of audio sources, and, whilst requiring greater specialist knowledge to set-up, could largely run autonomously once deployed.

3.2 AAR in Outdoor Learning Activities

A wide range of research exists, suggesting that learning undertaken outside of the traditional classroom offers significant potential both in heightening awareness of environmental issues, and in promoting empathy for the natural environment [1, 10, 17, 18, 28, 29]. In this work, we wished to examine the educational potential of the AAR system alongside use of experiential learning to increase and build engagement with nature and biodiversity.

There are many examples of how digital technology has been incorporated into outdoor learning activities. A GPS tracker, for example, can be used by instructors to remotely monitor a groups location whilst on an expedition and helps to maintain student agency, authenticity, and mastery [2]. Wrist worn GPS devices can also be used for navigation to back-up or even replace the more traditional map and compass.

SAMR (Substitution, Augmentation, Modification, Redefinition) provides a framework to evaluate the adoption of technology in an educational context [34]. *"The SAMR framework argues that technology adoption in education can move beyond the substitution of existing activities and assessment practices to create new experiences previously impossible or difficult with prior technology."* [8].

The SAMR model demonstrates that through the use of AAR, outdoor experiential learning has been afforded the opportunity to provide *"...otherwise unavailable learning opportunities at the transformational levels of the model."* [43]. AAR allows us to create new experiences such as presenting sounds of life that are locally, regionally or nationally extinct. We can discover individual cognitive, behavioural and affective responses to animals or birds we choose to present. If the technology remains largely unseen the participants may not even know it is there allowing for an uninhibited authentic response to the performed sounds.

4 AAR IMPLEMENTATIONS

4.1 Pilot Study

4.1.1 Description. The study was carried out over two days in November 2018 in an area of mixed deciduous woodland in the Kielder Forest, Northumberland, UK. The woodland was crisscrossed by numerous footpaths which were utilised to guide the 'journey' of the participant and to locate the speakers. The purpose was to identify the benefits and challenges afforded by a linear journey through the woodland as well as a static configuration. This pilot study provided an opportunity to test if the presence of the speakers would in any way detract from the immediacy of the experience and illusion of reality. We also wanted to find out what narration would be required in order to induce imagination, and provoke emotional responses, beyond the augmentation of the natural soundscape.

In the linear set up it was envisaged that the participant would walk along a predetermined route and experience a range of sounds, triggered by the facilitator of the session. The location of these sounds would either be static, for instance to simulate a bird calling in a tree, or dynamic to emulate an animal being disturbed and running away from the participant.

The outdoor aspect of the experience and lack of mains electricity meant that a battery powered approach was chosen. This brings the additional benefit of portability and rapid reconfiguration of equipment, should this be required. Use of wired connections was avoided wherever possible, notably between the audio interface and loudspeakers. Custom enclosures and Li-ion battery packs housed receivers for each speaker. The main equipment used included:

- An Apple MacBook Pro, running various digital audio workstation software packages
- A Tascam 1608 audio interface powered by a 12v sealed lead-acid gel battery
- Six MiniRig2 15-Watt battery powered active speakers
- Two Amphony Model 800 4-channel 2.4 GHz wireless transmitters
- Six Amphion Model 800 2.4 GHz wireless receivers

Each of the speakers was assigned a channel, meaning it was possible to play different sounds on each speaker, to pan between speakers, or to playback on a subset of speakers, depending upon requirements. The audio interface, laptop and wireless transmitters were housed in a location roughly equidistant to each of the receiver and speaker positions.

The custom enclosures (Figure 1) held the hardware to facilitate the wireless reception of the audio signals. These allowed each receiver to be switched on and off as well as providing a short cable connection to each speaker. Whilst Bluetooth speakers were considered we determined that the range needed was too great and there was uncertainty about the ease of being able to address multiple Bluetooth speakers from common DAWs.

Figure 1: Enclosure and MiniRig2 speaker in Kielder Forest

It was found useful, when checking connectivity and reproduction levels, to use a set of harmonic partials, such that each speaker would independently play a sine tone burst for a few seconds before the next speaker in line would play the next tone, culminating in all speakers simultaneous playing together. This meant that it was easy to aurally identify if there was a bad or erroneous connection.

To evaluate the experience, we experimented with a range of different sounds, consisting mainly of animals, birds and other environmental sources. Different options for speaker positioning, distance from transmitter, panning and reproduction levels were evaluated, as well as a range of sequences to produce a short story, or to emulate a specific source moving around in the woodland.

4.1.2 Reflection. Once levels were balanced and suitable positions found, the reproduction of nature sounds in the forest environment was convincing and engaging. Audio fidelity was at times poor since some of the samples exhibited a high noise floor. Whilst there was a tolerance for noisy samples, anecdotally masked by the wind and rustling of surrounding trees, significantly poor-quality audio easily broke the illusion that we were attempting to present. The other major problem encountered was the distance and practicalities of the wireless audio transmission. Wireless reproduction had worked well indoors, but once outside in the forest, we found that audio channels would intermittently or completely fail once distances of approximately 10 to 15 meters between transmitter and receiver were exceeded. This was compounded by the receivers seeming to be dependent upon line of sight to the transmitter, which was unusual given their reported mode of transmission (microwave).

In terms of the software used, both the DAW and game audio middleware performed well. It was observed that panning of sounds required more thought when using middleware, since directionality of sources is normally rendered by the virtual microphone position in the game itself. Without creating a companion game, this meant that quickly producing a story using game audio could be time-consuming. Both the DAW and game middleware made it relatively quick to construct scripted experiences using a library of sounds, which could be panned around the forest space and distances emulated well.

Overall, the pilot study was successful and demonstrated the potential of our idea. We managed to create pleasing experiences, albeit ones that were constrained by several technical challenges. Like any performance, if the wall of illusion is broken it is quickly noticeable to an audience and hard to regain. If wireless connections were to be continued, then it would be necessary to look at better options specifically tailored to outdoor audio transmission. It was also clear that the sounds presented were sometimes difficult to detect against the normal ambient soundscape and that having someone to guide an audience would be beneficial.

4.2 Timber Festival 2019

4.2.1 Description. Timber: The International Forest Festival[1] took place over three days in July 2019 at Feanedock, UK in a 70-acre woodland site, which is part of the National Forest.

Our AAR experience was presented as an installation at this medium-sized arts and music event. This provided an opportunity to use a setup that would remain fixed over the three days of the festival. Furthermore, there was potential for a larger audio reproduction system to be able to compete with any background noise. The possible pitfalls and restrictions encountered when using wireless speakers, observed in the pilot study, could also be avoided. The main equipment we used included:

- An Apple MacBook Pro, running Adobe Audition CC 2018
- A Steinberg UR44 audio interface
- Two Behringer Eurolive B208 170-Watt active speakers
- Two Behringer Eurolive B212 345-Watt active speakers

The area allocated for the experience was a clearing in a relatively sparse wood. The four loudspeakers were approximately positioned in each 'corner' of the clearing, resulting in a configuration akin to quadraphonic. The speakers were hidden behind the trees and bushes at the edges of the clearing, so as not to be easily seen by participants. The largest two speakers were placed on the ground due to their size and weight, whilst the smaller speakers were fixed to speaker stands, elevated to head height. Prior to each presentation, the system was tested for functionality by using the harmonic partials approach, described earlier, and a subset of sounds from the experience itself.

During the experience, one of the researchers operated the computer and audio interface and was hidden from view of the participants by the trees and foliage. Meanwhile, another researcher facilitated the experience and prompted the participants with an introduction, questions, and so forth. In order to meet the focus

[1] https://timberfestival.org.uk/

Table 1: Nature Soundscapes - Description of Scenes and their Characteristics

Scene	Duration (mins)	Sounds
Diurnal cycle	17	Blackbird; Robin; Song thrush; Wren; Chiff chaff; Chaffinch; Chickens; Red deer; Roe deer; Grey squirrel; Red Squirrel; Woodpecker; Tawny owl; Barn owl; Common pheasant; Badger; Fox; Common toad; Common frog.
Unusual Sounds of Nature	15	Lynx; Grey wolf; Brown bear; Bison; European elk; Fallow deer; Muntjac deer; Wild boar; Howler monkey; Whales.
Noise and Unwanted Sounds	5	Traffic on a highway; Construction and building noise; Railway noise.

of the festival and to keep within time constraints a narrative for the experience was constructed. This was also pertinent given the broad audience that would be present at the festival. The previous idea of past, present and future soundscapes was drawn upon but not directly replicated. The resulting narrative consisted of three main scenes: a diurnal cycle; unusual sounds of nature; and noise or unwanted elements. Each included a range of sounds that was presented to the audience participants. The whole experience, including the discussion and facilitation lasted approximately 40 minutes. Table 1 shows a summary of the sounds used in each scene of the experiences and its duration.

4.2.2 Audience Evaluation. Soundwalks have been shown to be a valid subjective evaluation mechanism for soundscapes, since they are able to provide a fuller representation of a user experiences and that the use of questionnaires with Likert-style questions are an effective way to capture such data [7, 40, 42].

A questionnaire was devised for completion by participants at the end of their AAR experience, consisting of a total of sixteen questions. Fourteen of the questions invited responses on a 6-point Likert scale to indicate level of agreement (1: Completely disagree; 2: Disagree; 3: Disagree a little; 4: Agree a little; 5: Agree; 6: Completely agree), as well as an option to indicate that they did not know how to respond. These questions sought to elicit responses around four broad constructs: *Soundscape enjoyment*; *Soundscape engagement*; *Feelings of Calm*; and *Awareness of nature*. The final two questions asked participants to provide free-text responses to the prompts: *"What did you enjoy most about this experience overall?"* and *"What did you not enjoy most about this experience overall?"*.

A total of 17 people completed the post-experience questionnaire, eight identified themselves as being male and nine as female. A broad range of age groups were represented with brackets ranging from 25-30 to 70+. Eight participants considered themselves as living in a village, two in a town, and seven in a city.

Creating an enjoyable experience was an important element. As such, we wanted to find out how enjoyable participants found the AAR experience. The feedback obtained for soundscape enjoyment (Figure 2) shows a strong level of agreement and participants found the AAR experience positive, although there is some difference in responses relating to the way the AAR experience magnified the participants' perception of the festival.

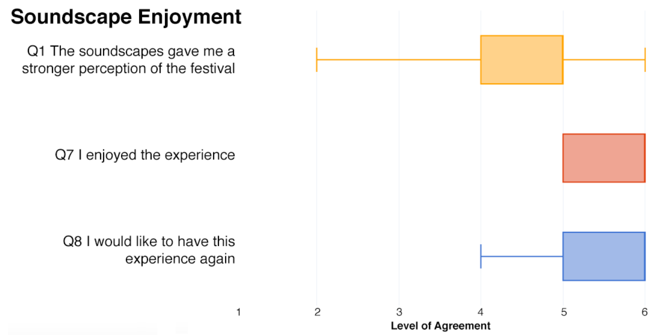

Figure 2: Enjoyment - Summary of Responses

In inviting responses relating to the participants' soundscape engagement (Figure 3), we sought to find indicators of immersion and flow in the AAR experience, suggesting that it cognitively connected with the participants. The data generally suggest that this was the case. Greater dispersion can be found in the ratings that relate to being aware of one's surroundings and interpreting this outcome is not without challenge. On one hand, being less aware of their surroundings may indicate a high-level of engagement. However, since our AAR experience was an augmented one designed to encourage participants to listen to the soundscape around them, responses that indicate greater awareness of one's surroundings could also be interpreted as a positive. Without additional context, it is not possible to account for this in a valid way.

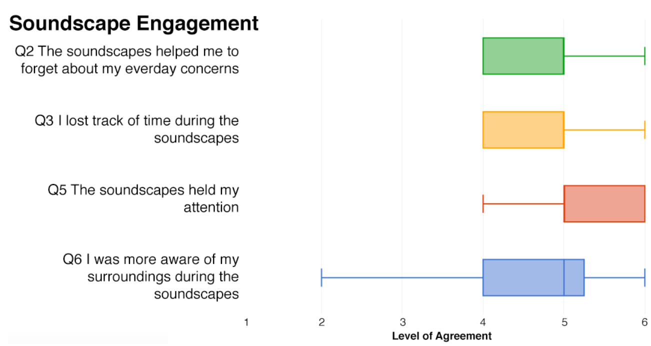

Figure 3: Engagement - Summary of Responses

Affective responses have been used as measures in other AAR experiences [42]. In the AAR experience, we relied heavily upon the bird and animal sounds, with a focus on the former, which may contribute to reduction of stress and promotion of calmness [36]. This effect was borne out in the responses relating to feelings of calm (Figure 4), with a notable reduction in levels of agreement in the case of human voices. This is perhaps not unusual since this was the only question within this construct that explicitly mentioned sounds caused by anthrophony, whereas the other questions dealt with either biophony, geophony, or the soundscape holistically.

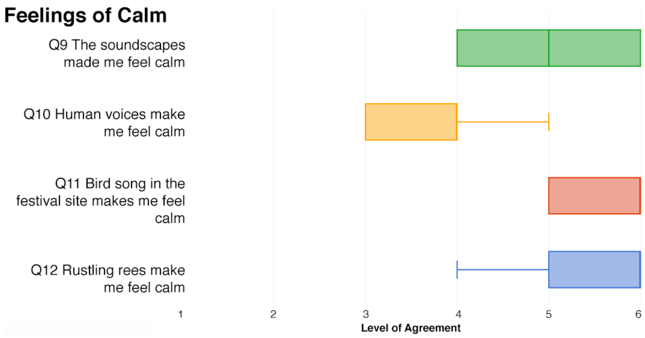

Figure 4: Feelings of Calm - Summary of Responses

Finally, we wanted to ascertain what connection and awareness of nature (Figure 5) participants had about the world around them as a result of engaging with the AAR experience. Responses were mixed with most participants agreeing that the soundscapes were effective in prompting them to consider the diversity of nature and the sounds that are, and might be, missing. The two questions relating to the ability of participants to identify the range of animals and birds presented is perhaps an indicator of the diversity of materials used in the experience (such as rare species or biophony that is difficult to detect under normal circumstances). However, it may also indicate a general lack capability to identify species in the group of participants.

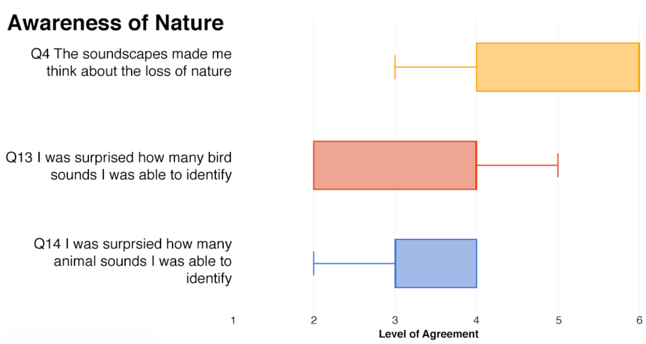

Figure 5: Awareness of Nature - Summary of Responses

The remaining free response questions produced a range of insights with almost all participants responding in both categories: 15/17 for positive aspects and 13/17 for negative aspects.

The most common theme from the positive comments related to the learning experience afforded by the AAR, with comments such as: *"[It is] Really difficult to ID sounds so great to have expert input. Learnt loads about sounds I've heard for years"* and *"Opportunity to learn new animal sounds"*. The second most common theme was of the sonic experience and the immersive, surround sound elements, receiving feedback such as: *"Surround Sound. Variety of sounds. Layering individual sounds from dawn chorus and then moved together"* and *"Immersion in what's already right in front of us"*.

The negative comments were concerned with background noise present at the site, due to the other activities of the festival, eliciting comments such as: *"Competition with other users of festival drowned out the sounds. Made me realise how difficult it must be for wildlife and also made me realise how much I must miss on a regular basis."*; *"Competition with the sound from the stages"*; and *"Being next to a tool workshop which made it problematic to hear the recordings"*.

4.2.3 Reflection and Lessons Learned. Overall, the nature soundscape AAR experience at Timber went well, with audiences and the researchers finding them entertaining and informative. The physical cabling between the audio interface and speakers was an inconvenience, especially as we tried to hide the cabling and speakers as much as possible. Access to a power supply was also difficult and due to adverse weather conditions some outages were experienced, although thankfully none of these happened during any of our experiences.

A key objective was to establish if audio augmentation of the environment would be recognised and induce a positive behavioural response. It became apparent at Timber Fest that the human participants were not the only ones making sense of, and responding to, the sound stimuli. The playing of sounds had a perceived impact on the local bird life too. As birds use calls and song to claim territory, the representation of a potential competitor had the potential to impact the behaviour of the local birds. The participants were able to highlight bird calls that we were not playing, suggesting that the local birds were responding to our recordings and as such no longer foraging, resting or feeding chicks. Instead they were changing their behaviour to respond to a potential invader of their territory [23]. It is difficult to suggest conclusively that our sounds had an impact on the local birds, however, it certainly warrants further research, with an assessment of the potential noise impacts of playing bird calls on the behavioural ecology of the local bird/wildlife suggested. It may be that permanent/fixed systems should be avoided and that choice of location and/or specific species recordings is carefully considered. A portable system is something that needs to be considered as it offers many advantages to both the local wildlife and from the potential implications associated with other users of the location (e.g. festival music), maintenance, management and landowner permissions to installation.

5 DISCUSSION AND FUTURE WORK

These outcomes confirm the feasibility of the nature soundscapes AAR experience. As a tool to improve experiential learning the use of AAR certainly displayed potential to enhance participants' knowledge and ability to identify bird calls. In order to move toward behavioural and affective responses the 'script' and the facilitator will play a key role and further research will need to be carried out to assess this and its ability to transfer [32] and retain the learning following exposure to the activity.

Once the whole system is working reliably, entertaining and engaging experiences can be created that are convincing. It is expected that further trial-and-error will be required in future, especially if a move back to wireless transmission is to be made. However, the reliability of a wired connection was found valuable, although it required time and resource overheads. The presentation of the experience at Timber festival was an installation and distinct from the scenario we originally envisioned the AAR system being used in. The current setup could be reused in a similar setting due to its reliability, but is likely to be impractical in mobile situations.

Our current plans for the system remain grounded in the use of loudspeakers. Although binaural audio, via headphone reproduction, is something that is of interest, this detaches the listener from the real world sounds in the environment. We consider this an important aspect of our AAR experience, since we want participants to pay more attention than usual to the soundscapes they experience in everyday life. For the next iteration of the AAR system we plan to use a hybrid of the two configurations described in this paper, involving wired connections between the audio interface and the speakers, but reverting back to the use of the smaller, battery powered speakers from the pilot study. We aim to move to a total of six channels over the four used at Timber festival. This provides many configuration options, such as retaining a quadraphonic setup but also having hidden, close proximity speakers, for example.

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