Sounds Aware: A Mobile App for Raising Awareness of Environmental Sound

Tate Carson
Louisiana State University

ABSTRACT

Sounds Aware is a web application that runs on a smartphone and uses machine learning to detect human-made sound (anthrophony) and masks it with ambient music as a user walks around their environment. A study was completed to determine if this app is an effective means of shifting a user's attention away from anthrophony and to biological (biophony) and geophysical (geophony) sounds while walking and encouraging environmental awareness. Though the model is pre-trained with the author's local environmental sounds, the user can train the model further on their unique soundscape so that each user gets a personalized experience. After the training process, the user can listen to ambient music based on traits of the surrounding anthrophony. If the app senses less anthrophony and more biophony or geophony, then the music fades away, bringing the user's attention to the anthrophony.

1. INTRODUCTION

Composer David Dunn poses an inspirational question:

> To what extent might the technologies of communication, art and entertainment serve as 'prostheses' that would provide us with experiences of wilderness that would not only enrich our human identity but help us to preserve and expand the domain of the non-human world [5]?

The goal of *Sounds Aware* is to bring the user's awareness to the geophonic and biophonic soundscape, which is often so masked by noise pollution that it has fallen out of awareness for many of us. *Sounds Aware* seeks to shift the user's concept of nature to something that has no starting or ending point; it is all around us. The app brings awareness by focusing attention on the environment. Because of the predominance of eye culture [3], our reliance on seeing rather than listening as a primary means of sensing the world, it is a lot to ask of a person who might be uninterested in acoustic ecology to "just listen" to their environment. But, if you give them a tool that urges listening in the quieter places, where the natural world will be more audible, there is a better chance of them engaging with those sounds because the app focused their perception. *Sounds Aware* is a means of technologically mediated "ear cleaning," as described by R. Murray Schafer in *Ear Cleaning: Notes for an Experimental Music Course* [13].

A 2011 World Health Organization (WHO) report found that "there is overwhelming evidence that exposure to environmental noise has adverse effects on the health of the population [10]." *Sounds Aware* shifts a users attention away from noise pollution and to nature, which may help mitigate adverse health effects caused by noise pollution. Psychologist Stephen Kaplan found that stress reduction can be aided by the experience of the natural environment by providing a 'restorative environment' that reduces the fatigue caused by directed attention [8]. Kaplan did not mention sound directly, but a recent study by Eleanor Ratcliffe *et al* [12] has extended his research to show that certain bird sounds may provide restorative benefits. While a reduction in environmental noise at the source would be the best way to solve noise pollution, masking the noise is a stopgap solution. A masking solution has been implemented by several projects [9, 15] but not yet with a mobile device. *Sounds Aware* implements a similar idea but with a mobile phone.

2. MOTIVATION

2.1 Soundscape

R. Murray Schafer suggests that we should listen to the environment as a musical composition. He describes urban and rural soundscapes as lo-fi and hi-fi. A rural landscape is hi-fi because there is a low noise level and allows one to hear more clearly. When in lo-fi (urban) soundscapes we are dealing with a lot of sound masking and getting less discernible aural information [14]. *Sounds Aware* brings attention to that urban noise by masking it with music, possibly reducing its negative effects as described by the WHO report [10]. The music of *Sounds Aware* and Schafer's 'environment as musical composition' combine as a duet to create a new unheard work.

Through our personal listening devices (smartphones,

Web Audio Conference WAC-2019, December 4–6, 2019, Trondheim, Norway.

iPods etc.) many of us try to block out the environment with music. Perhaps this is because we mostly hear noise pollution? This tendency makes *Sounds Aware* a viable tool for focusing attention because we are already used to making the choice to use personal listening devices. This is a tool that lets you continue to do that but brings your attention to the nature you might otherwise miss [18].

What could be gained besides a reverence for nature from *Sounds Aware*? Many of us use music as a way of blocking out silence. Rather than listening to the "silence," which might give us a chance to be silent in our minds, we fill up the space with music [18]. Perhaps *Sounds Aware* can recontextualize nature sounds to be engaging enough to pay attention to, to make the city soundscape seem uninteresting compared to the natural soundscape. *Sounds Aware* satisfies both ideas. By focusing the users' attention on environmental sounds, they will hopefully gain a greater appreciation for those sounds and then seek to design their world in a way such that my app is unnecessary. This redesign could take the form of urban planning that takes into account research from soundscape ecology [11].

2.2 Audio walks

Sounds Aware is further classified as an audio walk because it is a soundwalk mediated by technology. Johanna Steindorf describes audio walks as "experiments and works that combine walking and listening to a mediated soundscape over headphones [16]." That an audio walk takes place using headphones is important because it adds "a second layer of private sound to any place and situation, therefore transforming or enhancing the current spatial experience [16]." *Sounds Aware* mediates the public space through remediation of noise. The unique part of this audio walk is that the user is meant to be more aware when the composed ambient music is off. It is almost like a negative audio walk.

2.3 Ubiquitous listening

Urban dwellers are already often walking around with headphones in, trying to mediate the acoustic environment. Iain Chambers writes about the first entirely private listening experience, which provides a starting point for my app, the Walkman. This private experience that many of us first experienced with a Walkman, then CD players, is now experienced with mobile phones:

> With the Walkman strapped to our bodies we confront what Murray Schafer in his book The Tuning of the World calls a "soundscape," a soundscape that increasingly represents a mutable collage: sounds are selected, sampled, folded in and cut up by both the producers (DJs, rap crews, dub masters, recording engineers) and the consumers (we put together our personal play lists, skip some tracks, repeat others, turn up the volume to block out the external soundtrack or flip between the two). Each listener/player selects and rearranges the surrounding soundscape, and, in constructing a dialog with it, leaves a trace in the network [7].

Chambers notes that the music people were listening to was collage based, as was the way they were listening to it. He surmised that the way people would listen while walking around would change depending on the sounds of the outside environment. The sounds around the listener became part of the collage of the sounds playing on the Walkman.

3. RELATED WORK

The Quiet Walk [1], by Alessandro Altavilla and Atau Tanaka, is locative audio walk artwork for explorations of the urban landscape, where the goal is to find the quietest place in an urban location. The app notifies users if the surrounding sounds are too high. It also records the GPS locations of quiet places that are found so that the user can view a sound map of their walk. This might be the project with the closest concept to *Sounds Aware*, but there are some key differences. *The Quiet Walk* only records loudness levels and does not categorize sounds. Because of that, a loud anthrophonic sound is treated the same as a sound not human-made, which probably produced false positives. This more intelligent system was proposed in the conclusion and was probably not tried because of technological limitations of the time.

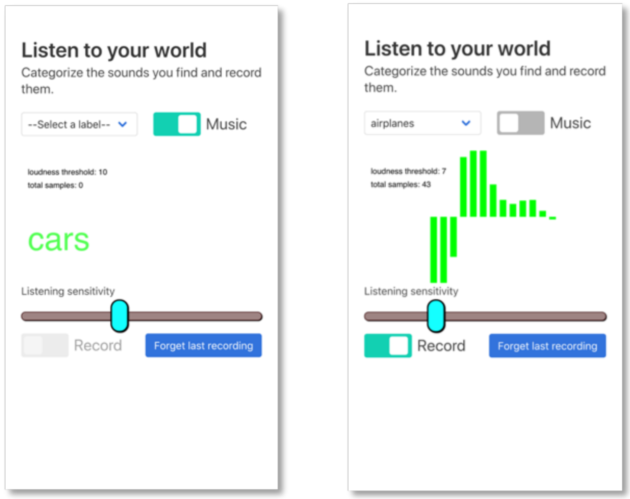
Hazzard, Benford, and Burnett created *Ambient Walk* [4], a mobile application that encourages mindful walking through sonification of biophysical data. The app plays ambient music dependent on users breathing patterns and the pace of walking. The authors intend for the music to keep a user aware of their 'balancing status' between walking and breathing. The intentions of *Ambient Walk* are very similar to *Sounds Aware*, though its intention is to raise the user's awareness of one's own mindfulness, instead of the soundscape.

There are many examples of smartphone apps that use GPS to teach the user about a historical subject. *Sounds Aware* does not use GPS but has similarities to apps that do. *Walk With Me* is a site-specific musical smartphone app that uses GPS to create geo-tagged markers to give form to a composition. This app is like *Sounds Aware* because it uses a microphone to sense the environment, but *Walk With Me* takes the step to alter that environment and turn those environmental sounds into part of the composition in a more conscious way. Specific places are chosen for their auditory characteristics and the piece is composed by giving certain locations specific acousitc qualities. The proximity to this geo-tagged location alters the signal processing, increasing the intensity as a user gets closer. *Walk With Me* does not have the same effect as *Sounds Aware* in raising awareness of a soundscape because it alters the soundscape instead of reframing it [17].

4. USER INTERACTION

Sounds Aware is accessed by going to https://walking.netlify.com in a web browser on a smartphone. It requires Internet access to download the default data set. After that, the app will work offline, so it is appropriate for various network conditions. Headphones are required so that the microphone on the phone does not pick up the music playback. Headphones with a microphone are preferred so that if the user wants, they can put their phone in their pocket while walking.

When a user first opens the application, they will see it guess the surrounding sounds based on a pre-trained data set. When assured that the microphone is working, the user can then start the music by clicking the toggle switch (see Figure 1a). The music now responds to what the surround-



(a) Playing music (b) Recording Data

Figure 1: Two states of the application

Tag category	Tags
Geophony	wind, other weather, rain
Anthrophony	cars, construction, human-speech, AC, airplanes
Biophony	insects, birds, large animal

Table 1: Data Tags

ing sounds. The user can adjust the listening sensitivity of the microphone to their liking to match the acoustic environment if it is particularly quiet or noisy. After testing the success of the system in interpreting the user's environment, the user can now add their own training data (see Figure 1b). For this, the user will select a sound category such as a car. Then the user will wait for a car to drive by and then record it by clicking the record toggle. This will make the system more accurate in listening to the user's specific environment. Users are not currently able to add their own sound category tags.

5. DESIGN

5.1 Technical design

Sounds Aware is built with Tone.js, a Web Audio API framework. There are a few downsides to web-based apps, such as cross-browser compatibility issues with microphone input, but a web app was chosen because a user might be more likely to try it if they do not have to download an app.

Each user starts off with a author-defined database of tagged sounds. To create this database each recording made was tagged (see Table 1) with a general sound category. Those sounds were then placed into broader categories of origin. This allowed the composition to treat sounds from different sources—geophony, anthrophony, and biophony—differently. Table 2 shows the default data set. Footsteps were treated as silence because the system needed to work when a user was moving. If they had been added to the anthrophony the system would only work if the user was still and silent; this was a trade-off to allow for user mobility, allowing them to find various soundscapes. More data could have been added to this data set to make tags more accurate, but for this proof of concept the most important tags were accurate enough for users to hear a result in the sounds.

Tags	Data points
wind	358
footsteps	361
birds	108
rain	107
cars	284
construction	62
Total	1280

Table 2: Training Data

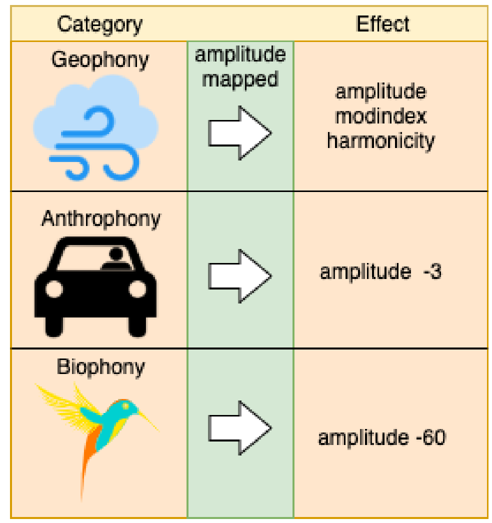


Figure 2: Mapping of tag category to music

The app uses machine learning to identify sounds. The algorithm used is k-nearest neighbor. A Mel-Frequency Cepstral Coefficients (MFCC) audio feature was used to compare sounds, implemented by Meyda.js[1], a JavaScript feature extraction library. Using Meyda.js allowed the processing to be done on the client, allowing *Sounds Aware* to work offline when necessary.

5.2 Composition design

The musical composition of *Sounds Aware* is influenced by ambient music. Synthesized sounds were used that would not be too jarring to jump in and out of and did not have an obvious beginning or ending. This type of synthesized sound blends in with the surrounding acoustic environment as a composition. The synthesized sounds are simple frequency modulation synthesis with reverb and delay effects. They are tuned to just intervals so they are more likely to coincide with tunings in nature, influenced by Aeolian practices [2] and La Monte Young [6].

The app maps the loudness[2] of the acoustic environment to the amplitude of the ambient composition (see Figure 2). The previous 200 loudness values are averaged and the am-

[1] https://meyda.js.org/audio-features
[2] A perceptual feature from https://meyda.js.org/audio-features.html

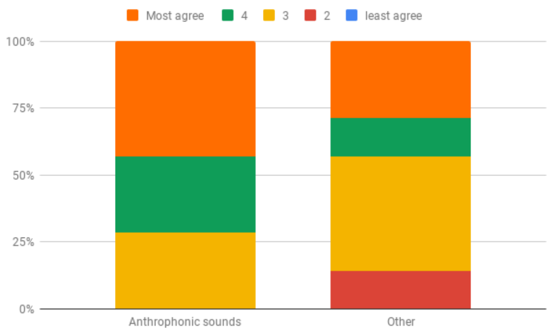


Figure 3: Sounds a user noticed in their neighborhood

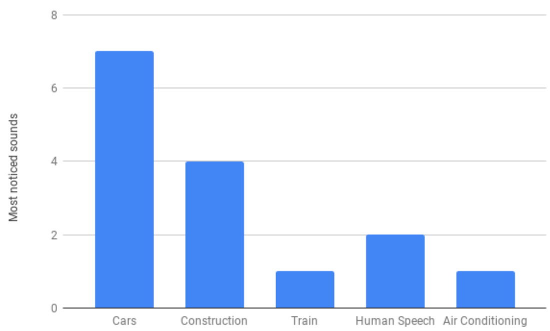


Figure 4: Noticed anthrophonic sounds

plitude ramps to a given value over one second for signal smoothing. If *Sounds Aware* hears an anthrophonic sound, the amplitude is faded up to -3 dB. If it hears a geophonic sound, the amplitude of the geophonic sound is mapped onto the synthesized sounds amplitude, creating a wind chime effect. Geophonic sounds also affect the modulation index and harmonicity of the frequency modulation synthesis, creating a variety of timbres depending on the character of the current external soundscape. If a biophonic sound is recognized, the amplitude of the ambient wash is faded down to -59 dB, which is perceptibly silent when listened to in an urban environment.

6. EVALUATION

The study begins with a survey designed to understand prior knowledge of environmental sounds and likelihood of interest in the project. Seven users took part in the study. The participants were anonymous and no demographic data was collected. The survey was conducted through a web-based question form. The participants were found through a university class and word of mouth.

Users were first asked, "When walking in your neighborhood do you notice a greater percentage of human-produced (anthrophony) sounds over biological (biophony), geophysical (geophony)?" Most users noticed anthrophonic sounds and slightly less noticed geophonic and biophonic sounds (see Figure 3). When asked the question, "Which anthrophonic sounds in your neighborhood are the most noticeable?" users noted cars and construction the most (see Figure 4).

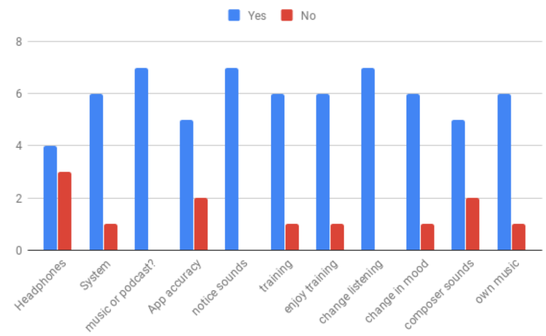


Figure 5: Exit Survey

For the exit survey, a number of questions were asked about how the app worked for the users and if it changed their awareness. The following questions were asked and represented in bar graph form (see Figure 5):

- Do you often walk around your neighborhood with headphones in?
- If there was a system to playback music when anthrophonic sound was detected but stop the music when biophonic or geophonic sound was detected, would you use it?
- Would it be more useful if you could pick the music, or even listen to a podcast?
- Did the app respond fast enough or accurately enough to cover up anthrophonic sounds?
- When the app did not detect any anthrophonic sounds, so did not play music, were you more likely to notice the geophonic and biophonic sounds?
- If the app was not accurate at first were, you able to train it with more data to make it more accurate to your soundscape?
- If you did try to train the system, did you find enjoyment in the act of training it?
- If you trained the app, did the act of training change the way you listened to the environmental sounds around you?
- Did you notice a change in mood or thought processes after having your attention drawn away from the noise and to the sounds of nature?
- Did you enjoy the composer-created sounds?
- If not, would the application be experienced better by being able to replace noise with your own music?

One issue with the study might be that a number of participants actually do not often walk around with headphones in. I suspect that in a much more urban environment than Baton Rouge, Louisiana, many more people would report walking while using headphones. Most participants were positive about the chance to try the app and also would like a way to use their own media with it. Five out of the seven users also thought the app responded quickly enough to be meaningful and the musical response matched closely with the current natural soundscape. All of the participants responded that they were likely to notice geophonic and biophonic sounds when there was a silence, which is a positive finding. Only one user responded that they were not able to retrain the app to make it more sensitive to certain tags and most enjoyed training the system and changed their listening during training.

7. CONCLUSIONS AND FUTURE WORK

Sounds Aware is a web application meant to increase a user's awareness of the biophonic and geophonic sounds in their urban environment. In limited studies, users reported increased awareness of environmental sounds. Having people use it over a longer period of time, and then surveying with more questions, would be a future avenue of research.

The app could have been made more robust by using native phone capabilities. A future version of *Sounds Aware* could be built using Capacitor[3], a native bridge for cross-platform mobile apps. This would allow the targeting of multiple platforms (web, iOS, Android) with the same code base and more robust access to native functionality such as the microphone. Usability improvements could be made such as the ability to add user defined tags so a user can record unique sounds in their location.

Other future work includes using an edge TPU computing board, such as the Coral Dev Board[4], to do machine learning computation on. An edge TPU (Tensor Processing Unit) would allow for more powerful machine learning capabilities in a portable form factor. This will make the system much more accurate and be able to recognize many more types of sounds. A study will be done to find out if this extra piece of hardware provides more benefits than costs.

8. REFERENCES

[1] A. Altavilla and A. Tanaka. The quiet walk: Sonic memories and mobile cartography. In *Proceedings of the 9th sound and music computing conference*, pages 157–162, Copenhagen, Denmark, 2012.

[2] R. Bandt. Taming the wind: Aeolian sound practices in australasia. *Organised Sound*, 8(2).

[3] J.-E. Berendt. *The Third Ear: On Listening to the World*. H. Holt, New York, 1992.

[4] S. Chen, J. Bowers, and A. Durrant. 'Ambient walk': a mobile application for mindful walking with sonification of biophysical data. In *Proceedings of the 2015 British HCI Conference*, pages 315–315, Lincoln, United Kingdom, 2015. ACM.

[5] David Dunn. Wilderness as Reentrant Form: Thoughts on the Future of Electronic Art and Nature. *Leonardo*, (4):377, 1988.

[6] K. Gann. La monte young's the well-tuned piano. *Perspectives of New Music*, 31(1):134–162, 1993.

[7] Iain Chambers, Christoph Cox, and Daniel Werner. The Aural Walk. In *Audio Culture: Readings in Modern Music*, pages 129–133. Bloomsbury Academic, revised edition edition, 2017.

[8] S. Kaplan. The restorative benefits of nature: toward an integrative framework. *In: Journal of Environmental Psychology.*, 15:169–182, 1995.

[3]https://capacitor.ionicframework.com/

[4]https://coral.withgoogle.com/products/dev-board/

[9] G. Licitra, M. Cobianchi, and L. Brusci. Artificial soundscape approach to noise pollution in urban areas. *Proceedings of the Proceedings of INTER-NOISE*, page 11, 2010.

[10] W. H. Organization. *Burden of disease from environmental noise: quantification of healthy life years lost in Europe*. World Health Organization, 2011.

[11] B. C. Pijanowski, L. J. Villanueva-Rivera, S. L. Dumyahn, A. Farina, B. L. Krause, B. M. Napoletano, S. H. Gage, and N. Pieretti. Soundscape ecology: the science of sound in the landscape. *BioScience*, 61(3):203–216, 2011.

[12] E. Ratcliffe, B. Gatersleben, and P. T. Sowden. Bird sounds and their contributions to perceived attention restoration and stress recovery. *Journal of Environmental Psychology*, 36:221–228, Dec 2013. 00146.

[13] R. Schafer. *Ear Cleaning: Notes for an Experimental Music Course*. Clark & Cruickshank, 1969.

[14] R. M. Schafer. *The soundscape: Our sonic environment and the tuning of the world*. Simon and Schuster, 1993.

[15] D. Steele, E. Bild, C. Tarlao, and C. Guastavino. Soundtracking the public space: Outcomes of the musikiosk soundscape intervention. *International journal of environmental research and public health*, 16(10), 2019.

[16] J. Steindorf. Walk-Along with a Mediated Presence: The Audio Walk as a Mobile Method. *Wi: Journal of Mobile Media*, 2017.

[17] R. Van Rijswijk and J. Strijbos. Sounds in Your Pocket: Composing Live Soundscapes with an App. *Leonardo Music Journal*, pages 27–29, 2013.

[18] K. Wrightson. An introduction to acoustic ecology. *Soundscape: The journal of acoustic ecology*, 1(1):10–13, 2000.