

Mobile applications for environmental noise and soundscape evaluation

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ABSTRACT

In the past ten years, in parallel to the development of low-cost digital technology, we witnessed the increasing development of mobile applications deployed as environmental noise and soundscape evaluation tools. Firstly, this paper presents the results of a survey conducted through literature and market review covering the past 10 years, spanning from the release of the first app, Noise Tube, to the more recent ones, such as Hush City. Secondly, it discusses the benefits and challenges of using mobile apps for environmental noise and soundscape projects. In conclusion, considering the release of ISO norms on soundscape, it discusses the possibility to standardize the design and implementation of mobile apps for soundscape research.

Keywords: Soundscape, Mobile Apps, Citizen Science

I-INCE Classification of Subject Number: 66, 70, 81

1. INTRODUCTION

The interest for the acoustic environment of cities, its impact on human health, well-being and quality of life and its implication on design and policy planning has a rather long history that can be traced back to the anti-noise movements of the late XIX centuries and more recently to the so-called soundscape studies stemming from the research conducted by Michael Southworth in the US and by Murray Schafer in Canada in the late Sixties of the XX century¹.

In order to study and evaluate the characteristics of the acoustic environment different indicators, tools and methods have been developed in the course of the decades (e.g. sound pressure levels, noise meters, acoustic cartographies, sound maps and alike). At the European policy level, the 2002 Environmental Noise Directive² has established the indicators and tools that should be implemented by major cities of the Member States, i.e. noise maps: graphic representation of traffic noise pollution in a given area, for a defined period, by means of specific acoustical indicators.

However, in the past ten years, in parallel to the development of low-cost digital technology, we witnessed the increasing development of mobile applications deployed as environmental noise and soundscape evaluation tools allowing everyone to study the acoustic realm and contribute to addressing open questions in the field of environmental noise and soundscape research.

In order to evaluate the extent of this new trend and its impact on academic research, participation and policy planning, a survey was conducted through literature and market review covering the development of mobile apps for environmental noise and soundscape in the past 10 years. Firstly, this paper presents the results of the survey consisting in twenty-eight mobile apps, spanning from the release of the first app, Noise Tube, to the more recent ones, such as Hush City and Ambiciti. Secondly, it discusses the benefits and challenges of using mobile apps for environmental noise and soundscape projects. In conclusion, considering the release of ISO norms on soundscape^{3, 4}, it recommends including the design and implementation of mobile apps in the standards on soundscape.

2. A REVIEW OF MOBILE APPLICATION FOR NOISE AND SOUNDSCAPE EVALUATION

A screening of mobile apps available on the market to crowdsource and produce noise and sound maps was conducted through literature and market review⁵, by applying the following selection criteria: 1) Mobile applications for the collection of qualitative and quantitative data related to the acoustic environment, such as noise pressure levels and/or audio recordings and/or user feedback and/or pictures; 2) Mobile applications for representing the crowdsourced data by means of web-based/app-based maps, such as noise maps and/or sound maps.

Social media mobile applications – such as Facebook, Instagram *et similia* – were not included in the review. Furthermore, only the mobile applications covered by research publications (e.g. Ear-Phone) or implemented in the framework of research projects (e.g. CITI-SENSE) have been included in the survey, even if they were not yet or no longer available on the market.

The results of this survey, previously published in^{5, 6} and hereby outlined in Table 1, consist of twenty-eight mobile applications developed between 2008 and 2016, with a peak in 2014.

Table 1 State of the art of mobile applications for crowdsourced noise & sound maps. Image source (Radicchi et al. 2017)

Year of release	Name of the app	Availability on the market	Available for iOS	Available for Android	Geo-located data collection features				Sequential data collection process	Open data
					Audio recorder	Noise meter	Camera	User feedback		
2008	Noise Tube	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
2009	WideNoise	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No
2010	NoiseDroid	No	No	Yes	No	Yes	No	No	Yes	Yes
2010	NoiseSpy	No	No	Yes	No	Yes	No	Yes	Yes	No
2010	noTours	Yes	No	Yes	Yes	No	No	No	No	Yes
2011	The Quiet Walk	No	No	Yes	No	Yes	No	Yes	Yes	No
2011	URBANREMIX	No	Yes	No	Yes	No	Yes	No	Yes	No
2011	NoiseWatch	No	Yes	Yes	No	Yes	No	No	No	Yes
2012	CITI-SENSE	No	No	Yes	No	Yes	Yes	Yes	Yes	No
2012	Noisemap	Yes	No	Yes	No	Yes	No	No	No	Yes
2012	I-SAY Sound Around You	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes
2013	Soundscape Characterization Tool	No	No	No	Yes	No	No	Yes	Yes	No
2013	Ear-Phone	No	No	No	No	Yes	No	No	No	No
2013	radio aporee	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
2013	stereopublic	No	Yes	No	Yes	No	No	No	No	Yes
2013	SoundOfTheCity	Yes	No	Yes	Yes	Yes	No	No	No	Yes
2014	Cart-ASUR (linked to NoiseTube)	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes
2014	Geluidenjager	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
2014	Recho	Yes	Yes	No	Yes	No	No	No	No	No
2014	Record the Earth	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
2015	The Noise App	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No
2015	Sound City	No	No	No	No	Yes	No	Yes	Yes	No
2016	Aircasting	Yes	No	Yes	No	Yes	No	No	No	No
2015	Think About Sound	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
2016	Ambiciti (new version of Sound City)	Yes	Yes	Yes	No	Yes	No	No	No	No
2016	City Soundscape	Yes	No	Yes	No	Yes	No	Yes	Yes	No
2016	MoSart	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
2016	Audiospook	No	No	Yes	No	Yes	No	No	No	No
2017	Hush City	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The twenty-eight mobile applications are (in chronological order): Noise Tube, WideNoise, NoiseDroid, NoiseSpy, NoTours, The Quiet Walk, URBANREMIX, Noise Watch, CITI-SENSE, Noisemap, I-SAY Sound Around You, Soundscape Characterization Tool, Ear-Phone, radio aporee, stereopublic, SoundOfTheCity, Cart-ASUR (linked to Noise Tube), Geluidenjager, Recho, Record the Earth, The Noise App, Sound City, AirCasting, Think About Sound, Ambiciti (new version of Sound City), City Soundscape, MoSart, Audio Spook.

From among these twenty-eight apps, sixteen are noise meter-based applications and eleven are audio recorder-based ones. Only SoundOfTheCity works both as a sound recorder and as a noise meter, even if the data collection process of audio recordings and noise measurements is not sequential. The majority of these apps also allow for the collection of mixed data, such as noise levels and user feedback (e.g. Noise Tube, Cart-ASUR), audio recordings and user feedback collection (e.g. Think About Sound). As of January 31 2018, some of the mobile apps were no longer or not yet available on the market.

The review's results reflect the approaches applied nowadays to analyze and evaluate the acoustic environment: the noise-based approach and the soundscape approach. The former relies on quantitative indicators (e.g. acoustical indices) to measure and represent the acoustic environment; whereas the latter focuses on the "acoustic environment as perceived, experienced, and/or understood by people, in context"³ and it applies qualitative and interdisciplinary measures to evaluate and (re)present the acoustic environment.

Some apps were developed within the context of European funded research projects, such as NoiseTube, whilst others were results of academic context, such as NoiseSpy, I-Say Sound Around

You and SoundofTheCity. Some apps tackle the challenges of environmental pollution in an original way. For example, Ambiciti app addresses the combined environmental issue of air and noise pollution; whereas Hush City app addresses an open question at the European policy level, which is how to involve people in the identification and evaluation of quiet areas by effectively integrating the soundscape approach with the noise-based one, as indicated by the European Environment Agency⁷.

3. HUSH CITY APP: RESULTS AND IMPACT

The Hush City app is a citizen science and soundscape free mobile application for both iOS and Android, launched on the market on April 2017^{8, 5}. A second, improved version and the related open access web-app (<https://map.opensourcesoundscapes.org/view-area>) were launched in the summer 2018⁶. The aim of the Hush City app is to empower people to identify, access and evaluate everyday quiet areas in their neighborhoods, therefore contributing to their protection and planning by municipalities.

Using the Hush City app, the users can:

- 1) crowdsource their favorite quiet spots and share them with the Hush City community;
- 2) identify and access quiet areas in their city or in other cities worldwide, shared by the Hush City users;
- 3) filter the quiet areas according to the following parameters: sound levels of the quiet areas measured by the app; descriptors used by the users to tag the quiet areas; level of quietness as perceived by the users (*not quiet-very quiet*), visual quality and accessibility (*not good-very good*), as perceived by the users; and time (*morning-afternoon-evening-night*);
- 4) review their personal surveys and delete the quiet areas crowdsourced;
- 6) provide feedback on the Hush City project.

The most innovative aspects of the Hush City app regard both the data collection and the data consultation processes. Hush City app allows the chained collection in the context of complex, mixed (qualitative and quantitative) data in a limited timeframe (approximately 3 minutes) of the quiet areas. The Hush City app also offers the possibility to collect multiple datasets on the same location by the same user or by different users, therefore allowing for further comparative evaluation according to time variation (e.g. seasonal and/or day/night variations).

The qualitative and quantitative data collectable with the Hush City app consist of: audio recordings and related noise pressure levels measured by the app; pictures of the place where the sounds are recorded; user feedback on the quiet area where the sounds are recorded.

Given the complex nature of an environmental experience⁹, the questionnaire embedded in the Hush City app to collect user feedback is composed of 20 questions and structured in three different sections addressing soundscape, activities performed in the areas and general issues related to environmental experience. Reply options consist of: multiple choice, 5-point linear scales, free text.

Since its launch in April 2017, public interest on the Hush City app has grown and the crowdsourcing process, initiated within the context of a pilot study in a Berlin neighborhood, has spontaneously scaled up to worldwide level. As of 31 January 2019, 300+ users from all around the world have crowdsourced 1300+ everyday quiet areas, especially in Europe, in the United States and in Singapore. Berlin (G), Granada (S), New York (USA), Cambridge (USA), Bristol (UK) and Singapore are the most active cities (see Fig. 1).

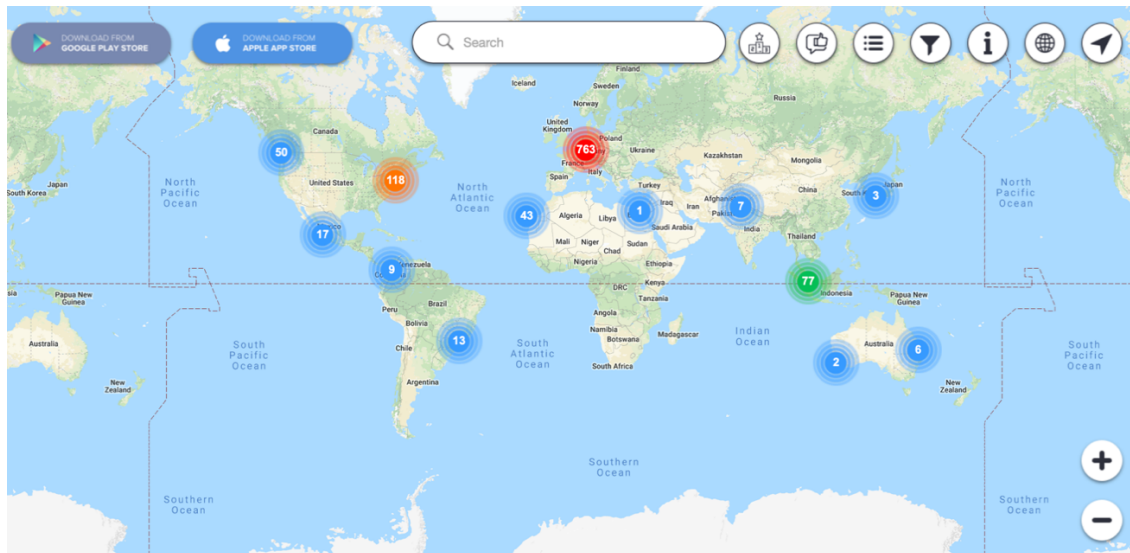


Figure 1: Image displaying the Hush City Map, with the everyday quiet areas crowdsourced worldwide with the Hush City app. Image source: map.opensourcesoundscapes.org/view-area

In Berlin, for example, 169 quiet areas were crowdsourced by 73 participants, mainly local residents and tourists. Overall, data collected in Berlin related to the 169 everyday quiet areas are composed of: 169 audio recordings, 169 sound pressure levels, 169 pictures and 3380 user feedback. This result led to the evaluation of the data by the Municipality of Berlin for the next Berlin Noise Action Plan (2018-2023). Furthermore, within the context of the public participation campaign launched by the Municipality of Berlin for the preparation of the 2018-2023 Berlin Noise Action Plan, the author was invited to lead two soundwalks so as to involve the public in the identification and evaluation of quiet areas in two different areas of Berlin, also by using the Hush City app.

In Bristol (UK), Sarah Jones-Morris – a landscape architect and director of the firm Landsmith Associates – along with Francois-Xavier Lallemand – an acoustical engineer at Ramboll – have launched a program of monthly public soundwalks to create a quiet map of Bristol, by using the Hush City app (<https://bristolsoundwalks.wixsite.com/brisoundwalks>). The program, supported by the Municipality of Bristol, aims at linking with Bristol’s Legible City project, with the potential of guiding future use, development and regeneration to positively impact on the future health of the city, people and nature.

In Granada (Spain), Prof. Vida Manzano of the University of Granada has launched a public crowdsourcing campaign involving both students of the University of Granada and local inhabitants of Granada. Up to the end of September 2018, more than 60 quiet areas were mapped, leading to a comparative study between the areas crowdsourced in Granada and in Berlin. The initial results of the comparative study were presented at the 176th Meeting of the Acoustical Society of America on November 5 2018¹⁰.

In Singapore, Dr. Siu-Kit Lau – senior lecturer at the Department of Architecture, National University of Singapore – and his students are currently studying the soundscape and quiet areas in Singapore using the Hush City App. The app is also being used in a course as a training and survey tool.

The implementation of the Hush City framework showed evidence-based positive impact¹¹ and it has the potential to assist planning authorities in complying with their duties under the Environmental Noise Directive EC 49/2002¹². It will also contribute to the health and quality of life wherever possible.

4. BENEFITS AND CHALLENGES OF USING MOBILE APPS FOR ENVIRONMENTAL NOISE AND SOUNDSCAPE PROJECTS

The review confirmed the trend of an increasing development and implementation of mobile apps for crowdsourced noise and sound maps. A critical reflection on the benefits and challenges of using mobile apps is therefore timely and necessary in the hope of orientating future research (Table 2 and 3). To produce robust data through mobile apps' crowdsourcing represents a challenge, which can be tackled by taking into account key issues which are hereafter discussed. The key issues (1-4) are drawn from an original framework developed in citizen science¹³ and they are extensively discussed in^{6, 13}. They are articulated in:

1) Interoperability. Under this umbrella term the following sub-themes can be included; data quality and standards, data sharing and access, data sharing with the participants, open data and licensing, software reuse, software reusability, data management & data privacy, data policy transparency.

2) Participant centered design and agile development. User-centered design (in the context of mobile apps) can help reach and involve participants. It also allows the project to be structured for mutual benefit, for both the scientists and the participants.

3) User interface and experience design. Design elements need to be "effective and efficient" and they should guide the participants through the steps to be taken: they might include the placement of the buttons and arrows, the overview of the workflow, the actions taken and the data gathered.

4) Motivational factors for participation. Several sub-themes can be included in this umbrella, such as citizen science, participatory planning, soundscape research, geography. Luna et al. suggest that a good participant-centered design process should bring relevant motivations to the foreground, by addressing one or more of the "six key motivational categories"¹³.

5) Acceptance. According to Königstorfer, technological innovation itself is not necessarily sufficient to be accepted in society, it needs to be negotiated in society and undergo complex decision-making processes among different actors^{14, 15}.

Table 2. The table summarizes the challenges using mobile apps in soundscape research. Challenges 1-4 are adapted from: (Luna et al. 2018). Table credits: A. Radicchi 2019.

Challenges of using mobile apps in soundscape research		
Challenges		Mitigation actions
1	Interoperability	E.g. Ensure data quality, data sharing with the participants, data reuse through CC licenses, data privacy
2	Participant centered design	E.g. By involving the participants in the design of mobile apps in each steps of the projects (start-to-end)
3	User experience design	E.g. By using "effective and efficient" design elements to guide the participants through the data collection process
4	Motivational factors	E.g. By bringing relevant motivations for participation to the foreground, addressing the "six motivational categories"
5	Acceptance ¹⁴	Technological innovation needs to be negotiated in society and undergo complex decision-making processes among different actors

Despite the fact that data collection through mobile apps usually has an unsupervised nature, this does not constitute per se a bias related to effectiveness of integrating such applications into scientific studies. Conversely, when properly designed and built, mobile apps could definitely become a fundamental part of the soundscape tool-kit and, eventually, be included among the methods and tools standardized by the ISO norms on soundscape^{3, 4}.

Table 3. The table summarizes benefits of using mobile apps in soundscape research. Content source: (Radicchi 2018). Table credits: A. Radicchi 2019.

Benefits of using mobile apps in soundscape research		
1	In-situ evaluation	The use of mobile apps fulfills the definition of soundscape ³ , leading to in-situ evaluation conducted by people in context
2	“Intimate sensing” ¹⁶	It favors the return to an “intimate sensing” of places, counter-balancing place-detachment inducted by remote sensing
3	Participation	The unsupervised nature of data collection is an added value, enhancing public participation
4	Data collection	It helps gather mixed data (including binaural recordings) related to specific issues, complementing traditional noise maps
5	Awareness	It contributes to raising awareness of soundscape quality & improves sensory skills
6	Comparative studies	It can facilitate comparative studies & inter-sectorial projects

Soundscape research addresses people and the way they perceive, understand and experience the acoustic environment in context³. Participation and public engagement are therefore crucial aspects to the successful implementation of soundscape projects. In this regard mobile apps and inherited platforms, when properly designed and built, can facilitate and retain public participation. By enhancing community involvement and exchange, mobile app technology can also favor the return to an “intimate sensing”¹⁶, a direct exploration of the territory and its interpretation in a comprehensive manner, according to the holistic nature of environmental experience⁹. In favouring in situ evaluation conducted by people in context, the use of mobile apps fulfills the definition of soundscape³. Furthermore, data collection by means of mobile apps can help gather mixed data (including binaural recordings) related to specific issues, complementing traditional noise maps¹⁷. The use of mobile apps can also facilitate the development of comparative studies & inter-sectorial projects, such as that study conducted by Radicchi and Vida Manzano in 2018 to evaluate commonalities and differences of quiet areas crowdsourced in the Nordic city of Berlin with those collected in the Mediterranean city of Granada¹⁰.

5. CONCLUSION

To study and evaluate the characteristics of the acoustic environment different indicators, tools and methods have been developed in the course of the decades. At the European policy level, the 2002 Environmental Noise Directive has established the indicators and tools that should be implemented by major cities of the Member States to study, evaluate and represent road noise pollution levels.

However, in the past ten years, in parallel to the development of low-cost digital technology, we witnessed the increasing development of mobile applications deployed as environmental noise and soundscape evaluation tools allowing everyone to study the acoustic realm and contribute to addressing open questions in the field of environmental noise and soundscape research.

In order to evaluate the extent of this new trend and its impact on academic research, participation and policy planning, a survey was conducted through literature and market review covering the development of mobile apps for environmental noise and soundscape in the past 10 years. Firstly, this paper presented the results of the survey conducted through literature and market review covering the past 10 years, spanning from the release of the first app, Noise Tube, to the more recent ones, such as Hush City. Secondly, it discussed the benefits and challenges of using mobile

apps for environmental noise and soundscape projects. In conclusion, considering the release of ISO norms on soundscape, it recommends that the design, building and implementation of mobile apps are standardized by ISO norms on soundscape research to favour the collection of robust data and the development of consistent comparative studies.

5. ACKNOWLEDGEMENTS

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