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Using mobile application to assess quality of acoustic and visual environment in relationship with aircraft noise

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ABSTRACT

Aircraft noise annoyance has been studied for more than 50 years, asking people to rate their annoyance on a unidimensional scale. The importance of non-acoustic factors shows that a more global approach could help to understand how people perceive their acoustic environment. Inspired by the soundscape studies, and in the frame of the ANIMA European project on the impact of aviation noise, an Experience Sampling Method with signal-contingent sampling is chosen to question people in their daily live about the quality of their acoustic and visual environment, and not on the annoyance. A dedicated mobile application is developed, which collects data each hour of a day (night periods are excluded). The experiment lasts two or three weeks depending on the number of notifications per day the participant found acceptable. After the notification, participants are asked to record acoustic measurements (third octave bands, each second during one minute). After the questionnaire, participants are asked to take a picture of the environment. Summary questionnaires are filled at the end of each week, and a global questionnaire is filled at the end of the experiment. This paper focuses on a pilot study whose aim is to evaluate the acceptability of the method by participants.

Keywords: Aircraft noise, Mobile Application, Experience Sampling

1 INTRODUCTION

The research activities of the ANIMA European project (Aviation Noise Impact Management through Novel Approaches) aim at improving quality of life of people living in airport regions. They should provide new insights on reducing annoyance and sleep disturbance, quantifying the effectiveness of a communication campaign in lowering annoyance and develop indicators and protection regime for night noise. In order to better understand annoyance, generally, perceptual data are collected through field studies. The performance of these studies is often burdened by several factors, such as the cost of sending- and back-collection of paper-pencil surveys the low response rate to participation requests, sometimes the disposal of test hardware (e.g. a notebook, a measuring device), etc. The crossing between perceptual and acoustic data is often only possible with calculated sound metrics.

Crowdsourcing data from mobile smartphones is a new method, which has been already used for noise monitoring in different contexts (1-3), and enables researchers to collect behavioural and acoustical data in-situ. Actually, this technology offers great opportunities because:

- more and more it can be assumed that everybody owns a smartphone, so there is no more need for handing out a mobile device, notebook for filling questionnaires or sending out paper-pencil questionnaires that have to be sent back once they are completed;
- participants can take pictures, record sounds and videos (in constantly developing quality, audio is approaching nowadays to measurement quality), participant's location can be determined, and

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(near) instant two-way dataflow is available between participant and the research team. Moreover, the progress of the test for individual participants can be monitored remotely, further on by the use of remote notification messages, in case of necessity, participants can be encouraged to do the study. Concludingly, smartphones can replace a whole number of different devices, are ubiquitously available and are easy to be carried along;

- accessing and thus acquiring (a huge number of possible) participants is much easier (e.g. through facebook, twitter, online portals, but former solutions – newspaper, postal letters, radio-announcement, random sampling on the basis of register data – still work), thus recruitment costs can significantly be reduced. However, it has to be noted that a statistically equilibrated sample selection from uncontrolled – possibly – mass of test data needs new approaches (e.g. through location-data, questionnaire filling-speed, demographical data, "tricky" cross-validation questions).

The ANIMA project will feature several small studies, internally referred to as "pilot studies", one of which is the development of a new mobile application, called ANIMA Research, nicknamed simply AnimApp (see Figure 1). Using the application, we aim to carry out an experience sampling [ESM] study about the impact of the sound- and landscape of the surrounding environment on people's perception of the environment and their quality of life around airports.

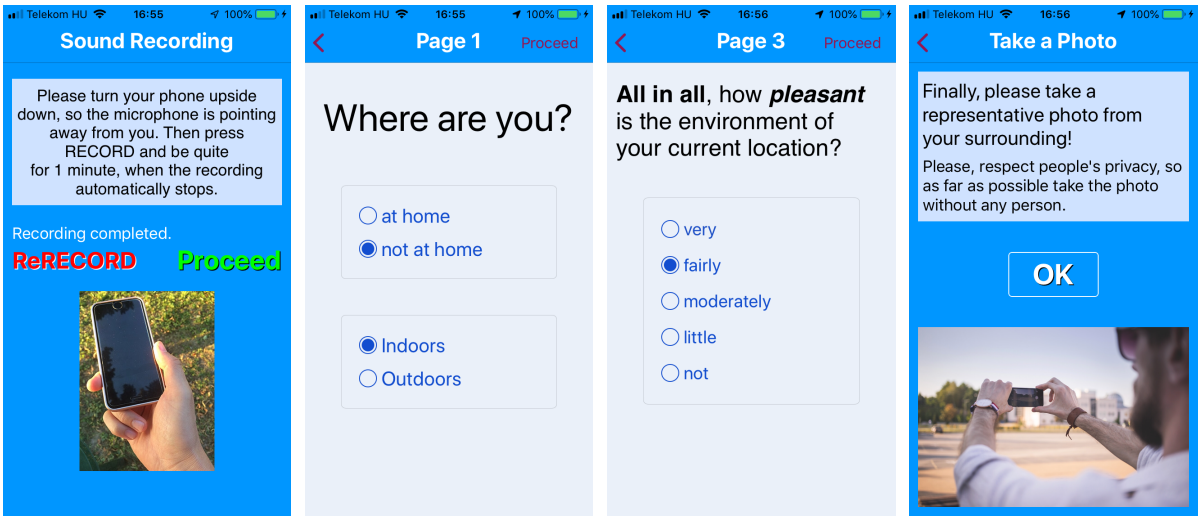

Figure 1 – Example screenshots of the Anima Research application 'AnimApp'

2 STUDY DESIGN

The development of the application has been divided into two phases:

The **pre-release stage** consisted of (i) the elaboration of the test-method (i.e. what should the participants be asked), (ii) the development of the App on both iPhone and Android platforms, (iii) performing the test by a few participants directly recruited by the research team, (iv) drawing conclusions on the feedback of the participants. As during such studies it is of key importance that participants don't get overly annoyed by the test itself, so they stop somewhere in the middle, not only the study procedure must be well designed (scientifically as well as in terms of attractiveness), but the app itself must be as far as possible error-free and user-friendly. Related to former field studies, where paper-pencil or similar (i.e. very basic) computer programs have been used, the achievement of these two latter requirements formed a crucial part of the pre-release stage.

The **release stage** will consist of (i) the refinement of the test-method, (ii) modification of the app and releasing it in the App- and Play-stores, (iii) recruitment of 60 participants around two airports (i.e. London-Heathrow and Ljubljana airports) for the ANIMA's pilot study on the impact of the sound- and landscape of the surrounding environment on the people's perception of the environment and their quality of life, (iv) performance of the study, (v) evaluation of the gathered data.

In this paper, the development of AnimApp at the pre-release stage is presented. The release stage will start in the fall of 2019.

2.1.1 Experience Sampling Method

Noise impact assessments are usually conducted by carrying out surveys in order to assess

retrospective judgments on long-term community responses to noise within a defined study area. However, real-life circumstances make new demands towards research and add variety to the data. Instead of forcing people to combine different experiences in different situations at different times of day and locations to a retrospective judgment at one point of time of measurement, the Experience Sampling Method (ESM) allows to assess the experiences in-situ repeatedly on different (consecutive) days at different times of day. Hence, the ESM approach can be characterized as "capturing life as it's lived" (4). By installing a survey-software on participants' devices, researchers are able to prompt for several assessments, whenever it appears to be necessary. Data is then submitted to a server and is available as soon as the upload is finished.

Although ESMs have been found to be useful in many scientific disciplines they have just shortly found their way into modern noise assessments (5). Here, we hope to have found a promising way to get a realistic insight into people's everyday noise experience, which we regard as essential when examining sound perception and its impact on quality of life in individuals.

2.2 Study overview

The followings are the elements of the test conducted by the app in the pre-release stage:

2.2.1 Introduction

After installing the app, during first start, the test procedure is explained, permissions are asked for location- and microphone usage, notification sending, and photo taking. In addition, settings have to be overviewed and adjusted at will, so the frequency and time-span of the test suits the participant's life style. Then the user exits the app. The application is designed as self-operating. Once installed, notifications will prompt for assessments at random intervals (see 2.2.2). The selection of momentary, weekly or the final questionnaire as well as the replacement of missed notifications are all automatically done without further intervention by the participants or the research team.

2.2.2 Momentary assessments

During weekdays, from 7 A.M. until 11 P.M. (when not shortened by the participant), once around each full hour the app sends a notification:

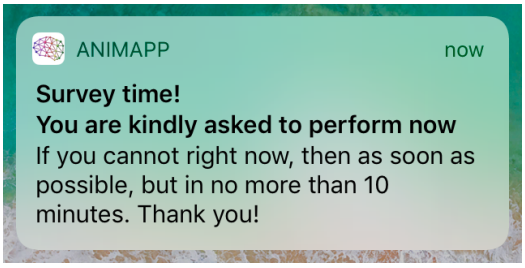

Figure 2 – Notification calling to perform an assessment

Depending on the user's preference 1-3 assessment notifications come a day. Hours of measurement (i.e. 7 A.M, 8 A.M, etc.) are randomized for the whole duration of the test, so the user doesn't know when the next measurement request will be prompted for. Each hour of the day is tested within the adjusted interval. The total duration of the study adapts correspondingly.

The user has to respond to a notification in 10 minutes and to start the so-called momentary - measurement consisting of sound recording, questionnaire filling and taking of a picture.

During weekend days, the participants respond to the same questionnaire, however in a shorter time frame, i.e. from 8 A.M. till 10 P.M. and just every second hour only.

2.2.3 End-of-week assessments

At the end of the work-week, i.e. on Friday evening, a short end-of-week questionnaire has to be filled in. Also after the very last weekend's momentary assessment, the same end-of-week questionnaire is asked relating this time to all *weekend* days during the test.

2.2.4 Final questionnaire

Once all week- and week-end hours have been performed, a final questionnaire is presented to the user asking for noise sensitivity, and standardized questions on well-being (6-7).

Note that in the context of this paper, individual actions driven by notifications are called *assessments*, while the whole process will be referred as the *test*. The ensemble of participants' tests is called the *study*.

2.3 Selected questions

Most studies on the impact of aircraft noise are based on standardized questions on annoyance and/or disturbances about a longer period of time (i.e. the 12 last months). This approach has led to the result that only up to about one third of the variance of reported annoyance is explained by sound level (usually average sound level such as L_{Aeq}, L_{dn} or L_{den}) (8). The ANIMA project tries to leave this classical approach moving from noise pollution and annoyance towards a more ecological point of view and the general notion of the perception of sound quality and its impact on quality of life. Actually, a soundscape approach may be useful to capture all relevant dimensions that can explain the impact of sound environment on people. Moreover, the often used indicator L_{den} is maybe not the best one for aircraft noise impact assessment (9); the association between more appropriate acoustic data and quality of life could be stronger than the correlation between L_{den} and noise annoyance. So it is worth trying to find better acoustic metrics than L_{den} which are closer related to the people's sound perception, as it is done with the soundscape approach (3). In order to be able to calculate most indicators that are proposed in the literature, the spectrum of the recorded sound (third octave band, each second) is stored. The aim of this application is to be distributed all over the airports after this pre-release and the release stages, so a strict calibration phase cannot be implemented, because people don't have the necessary calibration hardware. Therefore, later on during the analysis, only relative and not absolute acoustical metrics can be computed from the recordings.

At each moment when a notification is received by a participant, a series of questions appears after the sound measurement. The questions that have been selected are inspired from soundscape questionnaires (10-11), which have been recently standardized (12-13). The first dimension is the pleasantness of the sound, followed by the eventfulness, and the familiarity with the environment. The acoustic environment should also be described with the types of sound sources which are present in the environment. The context is not limited to the location (which is captured by the smartphone), but should concern also the activity of the participant at the moment of the evaluation. The context also has to include visual data. Actually, it has been shown that the quality of the landscape has an influence on the perceived pleasantness of a soundscape when people are outside: the greener the landscape, the higher quality the soundscape (14-16). When individuals are inside, the natural elements people could see from their windows reduced the negative affect due to noise (17). We aim to examine this further by asking participants to take a photo of their current surroundings after filling the questionnaire.

In the frame of our approach, we also want to question the rating of long term annoyance by means of single items: people feel disturbed at different moments of the day, or evening, or even night, but participants could have difficulties to produce a valid annoyance rating over a longer period time (e.g. 12 months) (5, 18-20). To examine how individuals add up all the different experiences deriving from their perception - at least for a one week period -, we decided to ask for the 4 questions on the environment (overall impression on the environment, sound pleasantness, landscape pleasantness, and representativeness of the week) at the end of each week.

Of course, the unexplained variance of noise annoyance could partly derive from personal dispositions. Accordingly, we assess the mood at each notification, and the noise sensitivity and the perceived quality of life at the end of the experiment. Noise sensitivity is assessed with one item. For the assessment of quality of life, the personal wellbeing index (6) and the WHO-5 index (7) are calculated.

3 DEVELOPMENT OF THE MOBILE APPLICATION

The description of the whole development process is out of the scope of this paper, so just selected major items will be presented here.

3.1 Platform selection

Nowadays Europe's smartphone market is practically (to 98.9%) covered with devices that run Android and iOS operating systems (21). While Android (73% - 26%) leads significantly, in some countries – like the U.K. – the share is near to 50-50%. As the region around London Heathrow Airport is one of the selected sites for the ANIMA's pilot study, it is clear that the development of the app had to be done for both operating systems.

From the point of view of developing difficulties, iOS is in better position because Apple's new operating systems always support older iPhones for quite a long time back. (The iOS 12, the latest OS, still runs on the iPhone 5S, which is 6 year old) On the other hand, on most Android smartphones the possibility of updates to newer operating systems is restricted. Market share is quite equally

distributed among the last 5 operating systems. This makes the development of apps quite hard.

From the distribution point of view, however, Android is in better position, because while Apple has strict rules (e.g. strong reasoning is needed for the use of privacy data, like location) and they also check each app (and version) before the app can appear in the App Store, Google's Play store has no such restrictions.

3.2 App design considerations

In regular field studies, the procedure of the study is in detail explained to the participants and once they agree to participate, they tend to comply well, which can be enforced by offering an expense allowance. Mobile apps are however completely different. They must be attractive enough, so the user downloads and starts to use it, while at the same time interruptions and disturbances of activities the app might produce have to be minimized to not corrupt compliance among the participants. Furthermore, to avoid long text based explanations, which might demotivate participants to stick to participate, we had to find a way of formulating instructions precisely and shortly at the same time.

Another difficulty is how to bring our test through, when the user often disregards the notifications to do a measurement. We either accept that fact simply and make our test procedure less strict (e.g. not all the hours have to be assessed, or the delay to start a given measurement can be (much) longer than 10 minutes) or – as it was in the pre-release version – we constantly say our user "OOUPS! I'm sorry, the survey must be performed not later than 10 minutes after the notification. Please wait for the next one" and risk thus the user gets so annoyed that he/she aborts the test.

Data sending needs also attention: on the one hand, apps should avoid running all the time in the background (and thus draining battery), but on the other hand they must make sure to send assessment data to us, once a measurement is completed. In our case, when internet is not available after fulfilling a measurement, there is no other option than to schedule data sending for later time. However, we ensured the battery will be drained as few as possible and even if the application is killed by the user the schedule for the upload of data still persist.

Finally tracking of the participants' location imposes further potential problems. In our study we want to know the position of the user at the time of the assessment, so that we can estimate the aircraft noise exposure for the respective positions afterwards and compare the calculated sound levels with the measured ones. Additionally, we ask our participants to allow following their coarse position all the time, so we have an impression how airport residents move during the day (i.e. to know – based on noise maps – how much they are exposed to aircraft vs. other noise). This latter functionality is extremely prone to battery drain, so it must be very carefully programmed and its unnecessary use can also be the reason for app-refusal at Apple. While the pre-release version, which was only distributed for testing, was approved by Apple, we hope that the release version, which will appear in the App Store, gets also approval.

3.3 Development issues

During development and testing we encountered several issues on both platforms: some needed special attention to cover all possible situations, other things, which should have work, simply not always do:

- Notifications: when a notification comes, the user can ignore, refuse or answer to it. Both operating systems have their own procedures to handle these actions, but it is important to take all possible scenarios into considerations, e.g. what happens when two or more notifications have been presented already and the user accepts the first one; what to do when notifications have been presented but instead of acting to them the user starts the app; how to repeat/dismiss a notification if the user seems not to act to one; define a proprietary notification sound (how long, how "aggressive") or use the system's notification sound.

  It was also of key priority that notifications drive the whole test-procedure. So it had to be made sure, that even if the app crashes or is killed and the user doesn't start the app any more, the next notification reliably comes and pushes forward the performance of the test.
- Data transfer: Apple's ecosystem practically does not support simple http post commands to normal (unsecure) servers, so secure connections must be established. This is also necessary in order to comply to data protection regulations. However, this increases difficulty of the development process and raises the necessity for iOS app's to send an Annual Self Classification Report to U.S's Bureau of Industry and Security. The development of the Android based application bore additional difficulties, by not providing built-in libraries for sending the so called simple multipart requests

– the most common data format to send files to a server. While Apple provides one, it is difficult to use. Ultimately both platforms needed external packages for data transfer, which unfortunately often didn't work as expected.

- Interferences by other apps: specific to smartphones is the ability that apps can anytime be interrupted by an incoming call, a notification (whether responded or not) or by the user directly. (In this app specifically: an incoming call while recording the sound; aborting the questionnaire filling for a while because of a chat-activity.) All these situations have to be carefully taken into account what to do if these things happen. Unfortunately even the presentation of a pop-up message, which vanishes in a few seconds, can break the normal app work-flow.

3.4 Randomisation considerations in view of missed notifications

For all field studies, from the point of view of later statistical analysis, the randomness of sample collection is very important. Therefore, to assure good randomisation among assessment hours and among participants, for AnimApp it has been decided (a) to let the participants perform an assessment at randomly selected hours (but along the test, each hour will be assessed just once), each day as many times as he/she set it up in the settings, (b) to define a 30 minute time-frame around full hours, to remove the last 10 minutes as reservation for delayed acting to the notification and then randomly select the exact time in the resulting time span (e.g. between 7:45 and 8:05), (c) to allow a maximum of 10 minutes delay after getting the notification.

On the Android platform, the randomisation was always performed only for the next day. If a participant missed a notification, the app tried to schedule a replacement hour on the same day. The result was that at the beginning of the test (before the completion of evening hours), the test-progress was faster, but had the drawback, that ultimately – in case of (a) missed notification(s) - the user was notified more often than originally intended and marked by the participant in the settings.

On the iPhone platform however, the randomisation was performed for the whole duration of the test right at first start (i.e. all notifications have been scheduled). When a notification was missed, the exact time-point was put at the end of the list, i.e. to the last day. The result was that a user was strictly as many times requested to perform a measurement as he/she specified, but that the total test period for this participant was longer.

All in all, both randomisation and rescheduling methods had its advantages and disadvantages, neither of them seemed to be more appropriate. For the test persons, one of the main problem was that the 10 minute allowed delay for a measurement was too short and thus led to frustration to get the "OOUPS" message so many times. For the release version therefore some alleviations will be made, which, unfortunately, will lower the total randomness.

3.5 Data security, privacy

AnimApp made several steps to respect people's privacy:

- It is not necessary for the users to enter any personal data to register in the study, they simply get automatically the next free user ID from the server during the first data-sending to the server. So users remain anonym.
- The sound recording is right on the phone transferred into a series of 3rd octave band spectra, one for each second, and only this is transmitted to the server. This keeps privacy in a natural way, as the original audio recording cannot be reconstructed from 3rd octave band spectra.
- The questionnaire data doesn't contain any personal information, so nobody knows from whom the given judgments come.
- During photo-taking the user is asked to respect people's privacy, by either avoiding any persons/faces on the photos, or by being far enough so that others are not recognisable. By not following our request, theoretically, we could have still collected photos from people. But as it turned out that picture taking is better to be replaced by a few questions, in the release version the option of picture taking will be skipped, so no more privacy issues can occur with regard to this aspect.
- A user has explicitly to agree to the all of the time (coarse) location tracking, but can also refuse. In the release version the obtained positions will be rounded to a grid of 100 * 100 m. This will further protect privacy.
- For any cases, during first start, a user must explicitly agree to our privacy policy, including the agreement that we collect/store/process data from the participant with his/her approval. However, in practice, we don't collect any sensitive data.

4 EXPERIENCES WITH THE PRE-RELEASE VERSION

The pre-release version has been tested during the winter 2018. A feedback questionnaire has been proposed to the "beta" testers. In general, the application is easy to tackle and works quite well. Nevertheless, it appears that there were some minor technical problems, but also some confusion on the evaluated items:

The sound measurement, which lasts one minute at the beginning of the evaluation, was not a constraint for testers.

The number of notifications is limited to three in this pre-release version. Some testers felt that more notifications a day would be appreciated especially when they have free time to carry out the experiment. Thus the number will be increased for the release version but will still be limited to a maximum of five per day in order to avoid a concentration of assessments on the same day.

The global duration of the experiment is quite long in the pre-release version. Actually, at the end of the experiment, if time slots are missing especially for week-end situations, participants have to wait till the next (week-end) day to fill the questionnaire. Moreover unintendedly missed notifications may be quite frustrating for a participant who wants to finish the experiment quickly. Thus, in the release version, some relaxing seem to be necessary to be made to the test procedure.

In the pre-release version, the visual pleasantness was asked in order to analyse the influence of the vision on the sound perception. This was justified by researchers who worked on the influence of natural elements in the landscape on the soundscape (see section 2.3). However during the pre-release phase, we realized that participants resided inside a room for most of the time. When asked for a photo, they tend to evaluate the design of the furniture and not the green elements through windows. We realized thus that taking a photo was more confusing than necessary. For the release version, we decided to skip taking a picture of the current environment, but added questions regarding the view to the outsides, if perceivable. When participants are outside, they also have to specify the type of landscape they see.

We realised that we did not ask for global sound assessment at the end of the experiment. However, there is no reason for limiting the global assessment only to the integration over one week and not to allow for judgments integrating the experiences over the whole test period (2 or 3 weeks)? Thus, it has been decided to ask the participants on the four environment assessments also at the end of the experiment (see penultimate paragraph of section 2.3).

5 CONCLUSION

A pre-release version of an application has been developed in the frame of the EU ANIMA project in order to study the impact of the sound- and landscape of the surrounding environment on people's sound perception and its impact on their quality of life around airports. The method of experience sampling [ESM] has been chosen because it captures subjective experiences as they are experienced in-situ in real life, and not assessed in a field study in terms of retrospective judgments aggregating responses to noise over a longer period of time.

Notifications to perform an assessment arrive maximum three times a day, and the test has been designed in order to collect assessments from experiences in every (awake) hour during week days and in every two hours during week-end days.

Perceptual data on the sound environment as well as visual environment are collected, in addition to acoustic data (third octave band spectrum each second during one minute) and taking a photo. Participants also reported about the context of the perceived environment, i.e. the current activity (working, relaxing, taking a meal, playing, making sport, etc.) and type of location (at home, at school, at shopping, etc. for inside or countryside, urban street, etc. for outside).

Feedbacks of "beta" testers guided the development of the release version. In general, participants found the pre-release version very easy to handle, but a little too long. The questions about the visual environment were not specific enough. They have been simplified in order to focus on the outdoor environment. Therefore, in the release version photos are not taken and stored anymore. Instead, the type of the landscape is assessed when outside and inside (if it is visible through window). The pilot study with the release version should start in fall 2019.

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