Reducing noise impact and improving quality of life by addressing annoyance

Roalt Aalmoes, Susanne Bartels, Sarah Benz, Stephan Grossarth, Dominik Hauptvogel, Julia Haubrich, Graeme Heyes, Paul Hooper, Dimitris Kotzinos, Julia Kuhlmann, et al.

Reducing noise impact and improving quality of life by addressing annoyance

Roalt Aalmoes[1] **Susanne Bartels**[2] **Sarah Benz**[3]
Stephan Großarth[3] **Dominik Hauptvogel**[2] **Julia Haubrich**[3]
Graeme Heyes[4] **Paul Hooper**[4] **Dimitris Kotzinos**[5]
Julia Kuhlmann[3] **Catherine Lavandier**[5] **Ferenc Márki**[6]
Uwe Müller[2] **Barbara Ohlenforst**[1] **Julia Quehl**[2]
Isabelle Richard[7] **Rui Roosien**[1] **Dirk Schreckenberg**[3]

[1] Royal Netherlands Aerospace Centre (NLR), Amsterdam, The Netherlands
[2] Institute of Aerospace Medicine, German Aerospace Center (DLR), Germany
[3] ZEUS GmbH, Germany
[4]Manchester Metropolitan University, United Kingdom
[5] CY Cergy Paris University, France
[6] Budapest University of Technology and Economics (BME), Hungary
[7] Environnons, France

Roalt.Aalmoes@nlr.nl

ABSTRACT

Aircraft noise is the most significant impact on communities residing near airports. But in addition to acoustical factors, non-acoustical factors also contribute to noise annoyance. In the ANIMA project, relevant indicators influencing the quality of life of residents living near an airport are identified. Literature studies, but also focus group meetings, workshops, and online surveys for communities near altogether nine different European airports are performed to understand the role of the airport and the implications on the well-being of citizens. Furthermore, it is intended to study what current communication strategies of the airports are and how they influence the impact of aircraft noise on residents' annoyance response and well-being. A detailed literature study as well as a re-analysis of data has been carried out to develop awakenings indicators for nocturnal fly-overs, as noise-induced sleep disturbance has been linked to adverse health effects and is also associated with annoyance. Another study will be conducted to understand human visual perception of aircraft and their noise levels using a noise simulator with Virtual Reality glasses, where different aircraft types and their noise impact will be compared in a laboratory study and later in an "in situ" experiment. Finally, people's perception of environmental sound near the airport and the relation with land use planning will be evaluated by developing a mobile application to be used around Heathrow and Ljubljana Airport. Together with a carefully crafted social media study, data on property-value and movement of people throughout the day, we hope to establish more evidence on the relationship between land-use planning, noise perception and quality of life. The outcomes of all studies will be tested later in intervention studies and, or integrated into a Best-Practice portal that will be available for airports, governments, communities, and other stakeholders.

1. INTRODUCTION

Aircraft noise has the most significant impact on the quality of life of communities residing near airports. But in addition to acoustical factors, non-acoustical factors also contribute to noise annoyance. More knowledge on new and effective interventions, besides the reduction of noise exposure itself, are required. In the ANIMA project, research and associated experiments are performed to enhance this knowledge. First, relevant indicators influencing the quality of life of residents living near airport are identified in Section 2. A number of pilot studies will be performed to examine how quality of life can be addressed, not just focusing on reducing noise impact, but annoyance in general. Lessons are learned from previous interventions at some of the major airports in Europe (Section 3.1). Measures to reduce annoyance are not always proven to be successful, even though indicators may point in the correct direction. For this reason, a closer look is taken upon communication strategies towards communities around airports. Focus group meetings are organized to get qualitative answers from residents (Section 3.2).

Undisturbed sleep is an essential prerequisite for health and quality of life. A detailed literature study as well as a re-analysis of data has been carried out to develop awakenings indicators for nocturnal fly-overs, as noise-induced sleep disturbance has been linked to adverse health effects and is also associated with annoyance. The outcome of this study is the development of awakenings indicator and protection regime for night noise (Section 4)

For understanding human visual perception in relation to aircraft noise, a Virtual Reality simulation environment is set up. Here, visual stimuli of aircraft (models) and environment are compared with audible stimuli of aircraft fly-over sounds in a laboratory experiment (Section 5). To improve knowledge on land-use planning around airports, three user surveying studies are defined in Section 6. First, a mobile application is developed for recording soundscape perception, and will be deployed around the airports of Ljubljana and Heathrow. Second, dynamic population maps of how people live and work around airport will be correlated with airport noise maps. This research is still in early stages and will not be discussed in this paper. Finally, social media channels will be examined in correlation with land use and property values to provide more insight into the relation between land-use planning, noise perception, and quality of life.

2. QUALITY OF LIFE

For decades airports, governments and communities have taken a limited approach to measuring the impact of airports on their environment. The positive impact is measured using the contribution to the gross domestic product (GDP), whereas the negative impact is often measured in terms of noise and other environmental consequences. In the meantime, 'Quality of Life' (QoL) is getting increasingly attention from academics, from industry and from the general public [1][2][3]. Using a broader assessment of the impact of an airport on its surroundings, allows for a better balance of the full range of positive and negative consequences associated with airport/aviation activity. Indicators for QoL could help airports and governments to better measure their impact, monitor progress and identify options for improvement. Following a review of various QoL assessment regimes, the EUROSTAT segmentation was used to provide a framework that allows categorisation of various meta dimensions of QoL (See Figure 1). For the collection of indicators, the team reviewed common general indices for QoL, 'wellbeing' and 'happiness' from multiple global sources such as the WHO, EUROSTAT and the 'Happiness Report' by the Sustainable Development Solutions Network [4] as well as national sources from Germany, the UK, and The Netherlands [5] [6][7].

The identified dimensions and associated topics and indicators found in this study are presented in an audit framework, which is intended as a good starting point to engage with wider community concerns. The framework should help airports to:

- Determine which dimensions and topics are already addressed
- Understand how specific interventions within topics are being evaluated and whether a link to QoL outcomes can be made
- Identify dimensions/topics that are not being addressed that the airport could/should be engaging with. Indeed these 'gaps' could form the basis of discussions with local communities as to what is regarded as most useful/beneficial foci for airport interventions

This activity could then inform the development of a QoL Strategy with defined activities, evaluation processes, targets, etc. Such an approach would also allow airports to provide a rationale for why certain QoL dimensions and topics are being given precedence whilst other may not be a priority (i.e. ones that airports could not reasonably influence).

Figure 1. Overview of Quality of Life indicators (picture courtesy of NLR)

Results of the ANIMA QoL study are published and a public version of the report is available [8].

3. INTERVENTION STUDIES AND COMMUNICATIONS STRATEGIES

3.1 Evaluations of previous interventions in improving quality of life

There is a vast amount of research studying aircraft noise-induced annoyance, factors influencing it and how it can be reduced [9][10][11].

However, only little is known about the quality of life of residents living in the vicinity of an airport and if and how it is affected by different interventions implemented by airports, the aviation industry, or public authorities. To evaluate the interventions and identify those aspects of an intervention that can positively influence residents' quality of life, a field study is carried out. The field study originally consisted of a qualitative and a quantitative approach. Due to COVID-19, the quantitative main survey could not take place. For the qualitative part, focus groups and in-depth interviews were conducted.

Four European airport regions were selected for this evaluation study: Frankfurt Airport in Germany, Marseille Airport in France, Schiphol Airport in The Netherlands, and Heathrow Airport in the United Kingdom. A total of three different interventions were assessed at the four airports. The selected interventions are sound insulation schemes, a flight path optimization (using fixed bend radius) and a consultation procedure. A sound insulation scheme was evaluated at both Marseille Airport and at Heathrow Airport. There is a flight path optimization used at Schiphol Airport, which was assessed, and a consultation procedure that took place regarding a possible

flight route change at Frankfurt Airport will be evaluated as well.

First, focus groups have been carried out to get a comprehensive and thorough understanding of the quality of life aspects relevant to residents as well as of residents' perception of the specific implemented interventions. A guideline was developed for the focus groups covering different topics and questions, such as residents' awareness of these interventions, how residents perceive and evaluate the interventions, and which aspects of these interventions have an impact on their quality of life. The focus groups and in-depth interviews were conducted at three research sites: around Marseille Airport, France, around Frankfurt Airport, Germany, and around Heathrow Airport, UK. Participants will be grouped into different groups, depending on the following criteria:

1) Participants neither eligible nor affected by the intervention,

2) Participants eligible, but who do not have/make use of the intervention,

3) Participants eligible, who have/make use of the intervention,

4) Pressure group members (if applicable).

Focus groups have been conducted around Marseille Airport (sound insulation scheme) and in-depth phone interviews were conducted for Frankfurt and Heathrow.

For the Marseille Airport region, the above described grouping criteria resulted in four focus groups: 1) no sound insulation and not eligible, 2) no sound insulation, but eligible, 3) with sound insulation, and 4) pressure group.

The focus groups discussions and in-depth interviews will be qualitatively analysed [12], enabling identifying quality of life aspects that are most relevant to participants and gaining insights into participants' perception and evaluation of the different interventions.

The results of this study will be used to provide valuable information on whether and how different interventions implemented by stakeholders affect the quality of life of people living in the vicinity of an airport.

3.2 Measuring the effectiveness of a communication campaign in lowering airport residents` annoyance

Non-acoustical factors like the attitude towards the noise source, trust in authorities and perceived fairness [9] contribute to a large extent to the variance in aircraft noise-induced annoyance. Many of these factors are hypothesized to be influenced by honest, transparent communication and information [18]. However, communication and information on aircraft noise issues is often too technical and complex to be understood by lay residents. The hypothesized path is that comprehensive and transparent communication and information enables airport residents to discuss aircraft noise-related issues competently and at eye level with the airport. Through this, an equitable exchange, an enhanced acceptability of regional air-traffic and a higher trust in authorities are intended to be achieved. For this reason, focus groups and in-depth interviews were conducted to identify needs and expectations from affected residents living around several European airports. Focus groups and in-depth interviews are qualitative research methods allowing deep insights in behaviour, perceptions and attitudes of complex issues [19]. The following points were discussed:

(1) The importance of aircraft noise and the airport for their quality of life,

(2) Perceptions of the current communication by and relationship to the airport, and

(3) Needs and expectations concerning information about aircraft noise and the airport in general, i.e., what information residents would like to receive from the airport and how this information should be prepared and provided.

Participants are living at the vicinity of (1) Cologne/Bonn Airport, (2) Dusseldorf Airport (3) East Midlands Airport and (4) Charles-de-Gaulle-Airport. Focus groups were conducted consisting of five to ten residents and in-depth interviews with one resident alone, which were either highly (> 55 dBA L_{DEN}) or slightly (< 45 dBA L_{DEN}) exposed to aircraft noise at their homes. All focus groups were mixed in age, gender and long-term annoyance due to aircraft noise exposure. They were carried out in municipal venues (e.g. schools) close to the residents' home or in-depth interviews via telephone. Focus group discussions and interviews were conducted based on a structured discussion guide designed for the study.

Subjects were asked to list relevant positive and negative factors influencing their quality of life. Factors were arranged by participants on a numerical rating scale ranging from „- 9 = strongest negative influence" to „+ 9 = strongest positive influence". After each person had placed his or her factors on the scale, the group was asked to find general terms for all positive and negative factors and to establish a ranking. Preliminary qualitative analysis of one highly and two slightly aircraft noise exposed focus groups at Cologne/Bonn Airport indicated that annoyance from nocturnal aircraft noise and air pollution from air traffic were listed as the main negative factors followed by a lack of security, cleanliness and missing infrastructure in terms of shopping and playgrounds. In terms of the positive factors, good infrastructures (i.e., schools, kindergartens, doctors) ranked first followed by good traffic connection and positive neighbourly relationship among residents.

With respect to the question what a good, fair, neighbourly relationship with the airport would look like, both slightly and highly aircraft noise exposed residents gave similar answers. One category of answers referred to technical and operational changes like a night flight ban and the airport`s promise to handle air traffic as quietly as possible (e.g. low-noise approach and departure procedures). Another category of answers refers to aspects of the relationship to the airport such as transparency and honesty, the feeling of being heard and being taken seriously. This was also voiced by participants' requests for cooperation and collaboration. Residents wished for an airport's attitude of being open to criticism and the willingness to negotiate.

At all airports, focus groups and in-depth interviews have almost been finished, fully transcribed and analysed using qualitative content analysis [12]. Based on the results, an engagement and evaluation guideline will be designed, since a planned intervention campaign cannot be implemented in the light of the current COVID-19 crisis. The main objective of these guidelines to provide

intervention strategies for an improved communication and engagement with affected residents as well as scientific evaluation criteria for these interventions. Recipients of the engagement and evaluation guideline will be aviation-related stakeholders (airport management, communities, politics) The aim highlights the importance and benefits of both an engagement process with the residents but also to evaluate such endeavours As part of the engagement guideline, a literature research on community engagement will be conducted. The importance of non-acoustical factors on annoyance and the QoL will be highlighted with an analysis of how aircraft noise is reflected in the regional media.
As part of the evaluation guideline, a questionnaire will be developed and tested that enable the measurement of perceived fairness in the context of aircraft noise. Moreover, the measurement of other key concepts (e.g. trust or knowledge) will be discussed and adequate questionnaires will be presented.

4. AIRCRAFT-NOISE INDUCED AWAKENINGS AS A MORE ADEQUATE INDICATOR FOR BETTER NIGHT NOISE PROTECTION CONCEPTS AROUND AIRPORTS

Undisturbed sleep is an essential prerequisite for health and quality of life. In times with nocturnal transportation noise as a growing problem, sleep disturbance is the main negative effect of nocturnal noise, known to increase the risks for adverse health effects and fatigue-induced accidents [13]. Current protection zones for nocturnal aircraft noise are mostly based just on average sound levels. However, these physical measures usually correlate only poorly with sleep quality. The number of aircraft noise events and their maximum sound pressure level are of higher relevance when it comes to noise-induced awakening reactions which are a physiological indicator for sleep disturbance and fragmentation [14]. Exposure response models explain the association between the maximum sound pressure level of an aircraft noise event and the probability for an awakening due to this event. Based on this model and air traffic data, the number of additional aircraft-noise induced awakenings can be calculated for every area around an airport and, then, can be limited in a protection concept that adequately considers human physiology.

In order to develop a generalizable standard exposure-response model, a re-analysis of the two worldwide available field studies [15][16] using the gold standard polysomnography and simultaneous acoustical measures was carried out. The data came from two international (cargo) hubs: one airport with continuous nocturnal aircraft noise (Cologne-Bonn) and another airport having a flight ban between 11 pm and 5 am but busy shoulder hours especially in the morning (Frankfurt Airport).

Data were pooled and a combined exposure-response curve based on the Akaike information criterion (AIC) was derived [17]. Besides the maximum sound pressure level ($L_{pAS,max}$) of an aircraft noise event, measured indoors at the sleeper's ear, the following additional acoustical parameters have an impact on the probability for an aircraft noise-induced awakening: (I) the time duration for an aircraft noise event above the background noise level, (II) the steepest increase of the sound pressure level from start of the noise event to the maximum level, (III) the A-weighted energy equivalent sound pressure level in the interval 1 min up to the start of the aircraft noise event (L_{Aeq3_1min}), and (IV) an interaction term between the $L_{pAS,max}$ and the L_{Aeq3_1min}, which means that it is relevant how much the aircraft noise emerges from the background level. The following personal and situational variables influencing sleep can be considered in the model as well (V) the sleep stage prior to the noise event (differentiating between shallower and deeper sleep stages as well as REM sleep), (VI) the elapsed time since falling asleep, and (VII) the age of the sleeper. The two latter factors are relevant since, both age and the time already spent asleep have an impact on the deepness of sleep. With increasing age as well as increasing time asleep, shallower sleep stages prevail which result in a higher susceptibility for an awakening.

The standard model will be used in ANIMA in order to generate maps around several EU airports indicating additional aircraft noise-induced awakenings and, thus, to improve existing night noise protection concepts.

5. HUMAN PERCEPTION STUDY

Amongst novel approaches that could enhance the communication between local planners and communities around airports, there are some virtual reality tools (auralisation and visualisation) which can be used by residents to give them better understanding of the impact of future airport scenarios in land-use planning, as the virtual reality creates a higher immersion for the user, See Figure 2. Such tools have proven to be convincing in

Figure 2. The Virtual Community Noise Simulator of NLR.

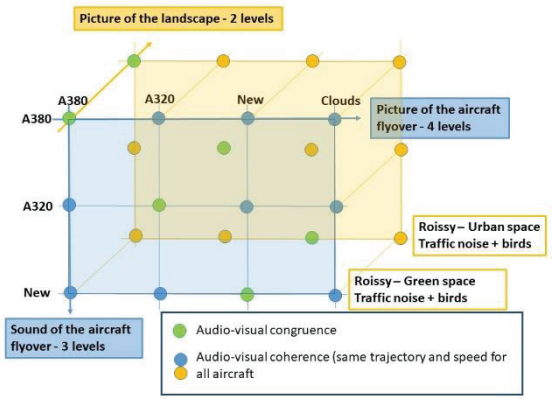

Figure 3. Design of the laboratory experiment.

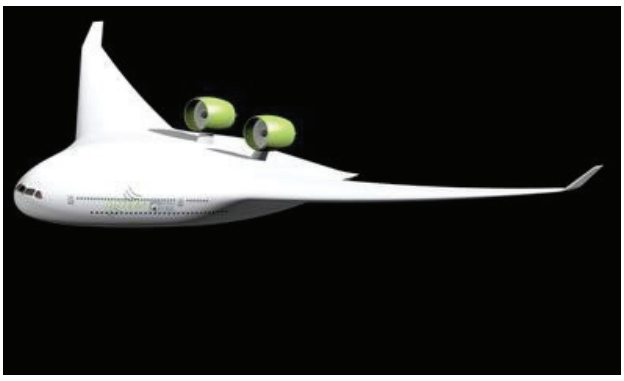

Figure 4. BOLT blended-wind aircraft 3D model, developed in EU ARTEM project by ROMA TRE University.

previous research and demonstrations [20][21][22]. Then, their ecological validity has to be evaluated.

A first laboratory perceptual experiment will be carried out in order to assess the relevance of such a tool for simulating flyovers in regards to realism, and to study the influence of the landscape (visual) associated to the background (audio) and to the vision of the aircraft (here the size and the architecture of the source) on the sound evaluation of the flyover.

Twenty-four stimuli will be synthesized (3 types of aircraft sounds x 4 types of visual aircraft sources x 2 landscape), See Figure 3. Among the aircraft, a revolutionary blended-wing design developed in the frame of ARTEM (another European project dedicated to technical sound characteristics of aircraft design) will be studied, See Figure 4. A sound auralization is developed by ONERA in the ANIMA project.
After each flyover, a questionnaire will appear in the virtual world, consisting of 4 differential semantic scales:
(1) The sound of this aircraft is more or less
Unpleasant/Unbearable ….. Pleasant/Bearable
(2) The noise level of this aircraft seems more or less
Strong/Loud ….. Weak/Quiet
(3) Does the association of sound with visual seem more or less Unrealistic/Inconsistent ….. Realistic/Coherent?
(4) Overall, does this situation seem more or less
Unpleasant/Unbearable ….. Pleasant/ Bearable?

After working on the validity of the virtual reality tool in laboratory, an in situ experiment will be organised in a city around an airport where an operational change of the aircraft route is planned. If people feel that they understand their environment and the influence of airport operations upon it, in theory they should feel in more control and thus more able to cope with change. The hypothesis behind this experiment is that the noise annoyance could be reduced with the use of such a tool, reducing fear about what will happen in the future.

6. USER SURVEYING

6.1 Mobile application

While studies reporting on quality of life are usually conducted as periodically recurring cross-sectional surveys, another approach was chosen here. The Experience Sampling Method [ESM] is a comparatively new approach in measuring human perception and response, promising to get more valid results, which are less affected by retrospective distortion and perceptual errors by measuring desired constructs in-situ [23]. It places the empirical phase of data collection into those situations and settings, where the cognitive, behavioural dispositions and affective components of interest acutely develop and occur [24][25]. To do so, we developed a collective of three short questionnaires:

1. A multiple times a day recurring momentary assessment of mood, behavioural and situational dispositions. We opted for at least two calls to perform an assessment a day, with a maximum of five calls per day around full hours, up until the participant has filled all wake hours. Start time can be adjusted between 7am and 9am; end time can be adjusted between 9pm and 11pm to respect participants' get-up and go-to-sleep preferences. Each momentary assessment will be preceded by a 60 second environmental sound recording. However, this is only to record 3rd octave band spectra.
2. A very brief weekly assessment survey asking for the overall representativeness of the daily collected data.
3. A final assessment assessing global parameters concerning participants' overall quality of life in general.

To participate and work through the assessments,

participants will have to install the purpose-built app ANIMA Research, which will, once it's installed, call the user in an automated way by means of notifications (like those when receiving an SMS) to perform assessments at random times in the above described time frames. To minimize interferences with participants' daily routines, calls to perform an assessment can be missed/ignored, which then will be rescheduled to another day. However, the whole survey must be fulfilled in a convenient maximum of four weeks. After this, the survey is aborted and the final questionnaire is presented to end the examination.

The app has been developed for Android and iPhone phones to assure best chances to get participants willing to take part in the study.

Key challenges during the development were:

1. To design a user-friendly app, so the participants do not abort their survey because they get bored/annoyed by the app itself. This includes attractive user interface as well as short but exact as possible texts/instructions (because people tend not to read long texts on their phones). A few pictures are shown in Figure 5.
2. To assure that the app delivers reliably the notifications to perform assessments.
3. To handle all possible unfavourable scenarios such as missed assessment calls, interrupted questionnaire fillings, the habit to "shut down" all running apps of the phone regularly etc.
4. And finally, to comply especially to Apple's app development guidelines and pass their review process to get approval to publish the app in the App Store.

After developing, testing and collecting experience of test participants for the first version of the app, the specifications and the app have been updated. This ensures that the app measures the variables of interest and is as user-friendly as possible. The final version is now under testing and will then be used around Heathrow and Ljubljana airports in spring/summer 2021.

6.2 Surveying through Social media

Social media have received a lot of attention the last decade as a source of information that relates to the opinions of the people on various subjects and tried to decide if those opinions were positive or negative [26]. There has also been an ongoing discussion on whether social media data can be used for large (behavioural) studies [27] and if so, how we can mitigate the bias that inherently exists in social media samples [28], since the participating population is not controlled. The main aspects of these discussions led us to design experiments around the use of social media data for understanding the sentiments of the population living and working around airports towards issues relating to the impact of the generated noise to their lives. We plan to mitigate most of the bias by working with large datasets (Big Data) coming from Twitter (www.twitter.com) and we plan to diversify our data sources by also retrieving and processing user comments from popular place evaluation sites like TripAdvisor (www.tripadvisor.com) and Yelp (www.yelp.com) where the impact of the noise can be assessed also by visitors and not only permanent residents. Moreover, we plan to extract some understanding from popular sites like Booking (www.booking.com) and AirBnB (www.airbnb.com) that are related to the renting of sleeping facilities in the area of airports and we will use those to assess the impact of the airport noise to the sleeping habits of temporal visitors.

We have so far started an effort to process and classify tweets that concern noise, using Heathrow Airport in Lindon, UK as our case study [29]. We manage to collect a set of tweets using both a space constrained method and a usual text-based comparison method and then we classified the tweets as relevant or not using a Machine Learning classifier based on SVM (Support Vector

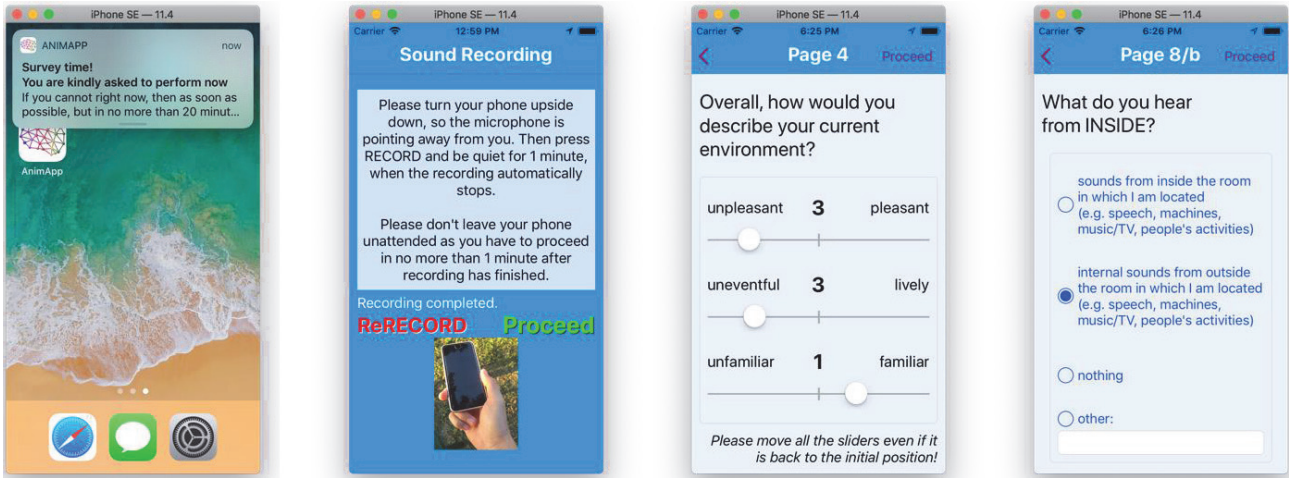

Figure 5. Screenshots of the ANIMA Research app.

Machine) [30]. After the relevant tweets were identified, we employed sentiment analysis methods to allow the characterization of the tweets as positive, neutral or negative. More precisely, we used aspects of the text like the presence of emoticons [31], the presence of specific words already identified to convey a positive or negative meaning with some scores assigned to them [32] and the polarity of the sentences, in order to finally classify a tweet as being positive, negative or neutral. So far, the results are quite promising but still preliminary. As described above, we plan to expand the pool of online sources we consider and at the end we plan to correlate our results with the results of the mobile application study that is described above.

7. CONCLUSION

Research on understanding the impact of noise, how to reduce it, and improve the quality of life of citizens affected by airport noise has been presented or published. Results are already available [8] or will become available later this year or next year. Outcome of the studies will also be translated towards best practices and used for intervention studies in the ANIMA project as well. A best practice portal will be set up, to let airports and other stakeholders implement future interventions in an effective way, addressing concerns of communities and reducing impact of noise annoyance.

8. ACKNOWLEDGEMENTS

This work has been achieved in ANIMA, a project that has received funding from the European Union's Horizon 2020 research and innovative programme under grant agreement #769627. The authors would like to thank other project partners and researchers, in particular Fiona Rajé, who contributed directly or indirectly to this work.

9. REFERENCES

[1] EUROSTAT. (n.d.). *Quality of Life (QOL)*. Retrieved from EUROSTAT website: http://ec.europa.eu/eurostat/web/gdp-and-beyond/quality-of-life

[2] EUROSTAT. (2017). Final report of the expert group on quality of life indicators. Retrieved from http://ec.europa.eu/eurostat/web/products-statistical-reports/-/KS-FT-17-004

[3] Garcia Diez, S. (2015). Indikatoren zur Lebensqualität. Vorschläge der europäischen Expertengruppe und ausgewählte nationale Initiativen. WISTA, 6, pp. 11-21.

[4] Beierlein, V., Morfeld, M., Bergelt, C., Bullinger, M., & Brähler, E. (2012). Messung der gesundheitsbezogenen Lebensqualität mit dem SF-8. Deutsche Normdaten aus einer repräsentativen schriftlichen Befragung. Diagnostica, 58(3), 145-153.

[5] Helliwell, J., Layard, R., & Sachs, J. (2017). World Happiness Report. United Nations.

[6] SCP. (2010). Wellbeing in The Netherlands - The life situation index since 1974. The Hague, The Netherlands: The Netherlands Institute for Social Research.

[7] ONS. (2017, April 6). Measuring National Well-being: Domains and Measures. Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/datasets/measuringnationalwellbeingdomainsandmeasures.

[8] R. Roosien, D. Schreckenberg, S. Benz, J. Kuhlmann, P.D. Hooper, D3.1 Review of indicators of Quality of Life, available at https://zenodo.org/record/1549205#.XminQ6hKguU, 2018.

[9] R. Guski: "Personal and social variables as co-determinants of noise annoyance", *Noise Health*, 1 (3), pp. 45–56, 1999.

[10] S. Sörensen: "On the possibilities of changing the annoyance reaction to noise by changing the attitudes to the source of annoyance", Stockholm: Tryckeri Balder AB, 1970.

[11] U. Felscher-Suhr, D. Schreckenberg, R. Schuemer, and U. Möhler: „Vertrauensbildung als flankierende Maßnahme zur Lärmbelästigungsminderung? – ein Vorschlag für eine interdisziplinäre Umsetzung in der Praxis", Paper presented at the DAGA 2001, Hamburg, 2001.

[12] P. Mayring: „Qualitative Inhaltsanalyse, Grundlagen und Techniken", Weinheim: Beltz, 2003.

[13] Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. Lancet, 383, 1325–1332.

[14] Basner, M., McGuire, S. (2018). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and effects on sleep. International Journal of Environmental Research and Public Health, 15(3), pii: E519. doi: 10.3390/ijerph15030519.

[15] Basner, M., Samel., A., Isermann, U. (2006). Aircraft noise effects on sleep: application of the results of a large polysomnographic field study. The Journal of the Acoustical Society of America, 119(5), 2772-2784.

[16] Müller, U., Aeschbach, D., Elmenhorst, E.-M., Mendolia, F., Quehl, J., Hoff, A., Rieger, I., Schmitt, S., Littel, W.(2015). NORAH - Verkehrslärmwirkungen im Flughafenumfeld, Endbericht, Band 4: Fluglärm und Schlaf. Gemeinnützige Umwelthaus GmbH, Kelsterbach, Deutschland, URL: http://www.laermstudie.de/fileadmin/files/Laermstudie/Schlafstudie_Wiss_Ergebnisbericht.pdf

[17] H. Akaike, "A new look at the statistical model identification," in IEEE Transactions on Automatic Control, vol. 19, no. 6, pp. 716-723, December 1974.

[18] C. Asensio, L. Gasco, and G. de Arcas: “A review of non-acoustic measures to handle community response to noise around airports”, *Current Pollution Reports*, 3, pp. 230– 244, 2017.

[19] R.A. Krueger and M. A. Casey: “Focus groups – A practical guide for applied research”, California: Sage, 2015.

[20] R. Aalmoes, M den Boer, Communiceren over geluid rondom windparken, Geluid, no. 2 pp. 9-12, April 2017.

[21] R. Aalmoes, M den Boer, H. Veerbeek, Virtual Reality Aircraft Noise Simulation for Community Engagement, INTERNOISE 2018, Chicago, IL, USA 2018.

[22] R. Pieren, D. Lauper, R. Zon, R. Aalmoes, J. Lourens, K. Heutschi, Demonstration of railway noise auralisation and visualisation, DESTINATE, report D3.2, February 2019.

[23] N. Bolger and J.-P. Laurenceau: “Intensive longitudinal methods: An introduction to diary and experience sampling research. Methodology in the social sciences, Guilford Press, New York, 2013.

[24] N. Bolger, A. Davis, and E. Rafaeli: “Diary methods: Capturing life as it is lived”, Annual Review of Psychology, Vol. 54, pp. 579-616, 2003.

[25] N. van Berkel, D. Ferreira, and V. Kostakos: “The Experience Sampling Method on Mobile Devices”, ACM Computing Surveys, Vol. 50, No 6, pp. 1-40, 2017.

[26] K. Ravi, V. Ravi. A survey on opinion mining and sentiment analysis: tasks, approaches and applications. *Knowledge-Based Systems*. 2015 Nov 1;89:14-46.

[27] D. Ruths, J. Pfeffer. Social media for large studies of behavior. *Science*. 2014 Nov 28;346(6213):1063-4.

[28] S. González-Bailón, N. Wang, A. Rivero, J. Borge-Holthoefer, Y. Moreno. Assessing the bias in samples of large online networks. *Social Networks*. 2014 Jul 1;38:16-27.

[29] I. Meddeb, C. Lavandier, and D. Kotzinos. Using Twitter Streams for Opinion Mining: a case study on Airport Noise. *Springer CCIS 1197*, in press.

[30] Cortes, C., Vapnik, V.: Support-vector networks. *Machine Learning* 20(3), 273–297, 1995.

[31] Yadollahi, A., Shahraki, A.G., Zaıane, O.R.: Current state of text sentiment analysis from opinion to emotion mining. *ACM Comput. Surv*. 50(2), 25:1–25:33 (2017)

[32] Asghar, M.Z., Khan, A., Ahmad, S., Qasim, M., Khan, I.A.: Lexicon enhanced sentiment analysis framework using rule-based classification scheme. *PLOS ONE* 12(2), 1–22 (02 2017). https://doi.org/10.1371/journal.pone.0171649,