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ICAO CAEP/12 White Paper: Non-acoustic factors in community annoyance due to aviation noise

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Abstract

This white paper provides a summary of our consensus understanding of non-acoustic factors as they apply to the community annoyance due to aviation noise. Non-acoustics factors firstly are defined in the context of how we currently understand annoyance. Various categorizations of non-acoustic factors are then enumerated, and a distinction is made between internal personal factors, external social factors, and external physical factors. Examples are given of both short-term and long-term coping strategies for human response to aviation noise. The results of several consensus science studies involved with non-acoustic factors are then summarized, and these include some key points from the CAEP 11 aviation noise impacts white paper, outcomes of the E.U. ANIMA project, some results from the U.K. Survey of Noise Attitudes, and findings from the U.S. Neighborhood Environmental Survey. Information is also provided regarding efforts in the ISO to develop a standard for non-acoustic factors. Overall summary conclusions and an extensive list of references complete the paper.

1 Introduction

In 2019, the CAEP ISG group published the White paper on aviation noise impact (Sparrow et al., 2019). One of the most prevalent responses to aircraft noise is the community noise response, which is measured in surveys, often by means of standardised rating scales (e.g. Fields et al., 2001; ISO/TS 15666:2003).

The 2019 White paper reports that survey results show large variations in annoyance. Referring to a rule of thumb proposed, for example, by Guski (1999), about one third of the variance of annoyance is explained by average noise levels, such as L_{dn} or L_{den}, another third is explained by so-called non-acoustic factors and the last third of variance so far is unexplained. The unexplained variance might be due to acoustically relevant factors that are not well captured by average sound levels such as the number of events, duration of sound, distribution of noise events over the day, or specific characteristics of the sound events, e.g. the intermittency of the sound (see e.g. Wunderli et al., 2015). Or, further non-acoustic factors not assessed in surveys or residual measurement error contribute to the unexplained variance of annoyance. This last point leads to the method of annoyance assessment.

Currently, three trends can be observed regarding the assessment of annoyance in real-life settings in socio-acoustic surveys, which are all relevant for the understanding of non-acoustic factors.

1. Update and, thus, continuation of the standardized assessment of annoyance by means of two single noise annoyance questions. In line with this, the ISO's technical specification

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ISO/TS 15666, originally introduced in 2003, has been recently updated (ISO/TS15666:2021; Clark et al., 2021). The updated ISO standard includes three recommendations with respect to the definition of the percentage highly annoyed (%HA). First, it provides a standard scoring and notation for %HA calculated using the upper three points (8, 9, 10) of the numerical 11-point scale, which should be depicted as $\%HA_N$. Further, there are two recommendations for the 5-point verbal scale: using the top two scores (4=very and 5=extremely) and note the outcome as $\%HA_V$ or weighting the verbal score 4 by a factor of 0.4 and use the reference $\%HA_{VW}$, with the latter definition aiming at narrowing the %HA based on the 5-point scale to $\%HA_N$. The international standardization has huge benefits as it allows to internationally compare research results, conducting re- and meta-analysis of a huge body of surveys, and modelling generalized exposure response relationships. However, some deficiencies exist (Richard, 2017; Sparrow et al., 2019) referring to the lack of considering the time of the day the annoyance is experienced and to a memory bias when judging the annoyance over a longer past period (12 months or so) time (Richard, 2017; Sparrow et al., 2019).

2. A more elaborated and psychometrical way to assess noise annoyance is to define subdimensions of a multi-faceted concept of annoyance and then to develop a scale of several items for each of these facets (Schreckenberg et al., 2018). Here, the aim is to overcome the potential problem of within-subject variability in annoyance judgments (lack of re-test reliability) when assessing annoyance with just one or two single unrelated questions. Further, it is argued that the noise-related social and political background may modify the annoyance judgments, sometimes purposefully, in order to foster responsible authorities' activities to reduce the noise (Fidell et al., 1988). Using multiple items for the annoyance assessment is expected to reduce this kind of response bias, and furthermore, makes the factors affecting the different components of annoyance more explicit (Schreckenberg et al., 2017).
3. The repeated assessment of short-term annoyance in an acute moment or in reference to a past short period of time (e.g. the past hour) several times per day across several consecutive days. These types of studies are called experience-sampling studies or ecological momentary assessments (Bartels et al., 2015; Fujiwara et al., 2017; Page et al., 2020; Schreckenberg & Schuemer, 2010). It is important to note, that long-term and short-term annoyance are similar concepts related to each other, but they are not the same as they refer to different situations and time frames. That has implications for the partly different role of non-acoustic factors for long-term and short-term annoyance (Bartels et al., 2015; Schreckenberg et al., 2010).

The authors of the 2019 White paper conclude that “Location and/or situation specific acoustic and non-acoustic factors play a significant role [in the prediction of annoyance] and must be taken into account” (Sparrow et al., 2019, p. 47).

This White paper aims at shedding light on the role of non-acoustic factors in annoyance. It should be noted, at the outset, that many of the references cited in this paper are not from peer-reviewed journal articles. It is the tradition in the area of aircraft noise that much research is performed by groups of consultants who don’t often publish in such journals. However, the consensus of the authors of the current white paper is that these references are appropriate for inclusion here and adequately represent the best current knowledge.

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2 Understanding non-acoustic factors of annoyance

2.1 Definition of non-acoustic factors

Non-acoustic factors of community noise annoyance are secondary, contextual and personal factors present in the noise situation, in the exposed person, or both.

Non-acoustic factors have been studied in socio-acoustic surveys on community responses to aircraft noise since the earliest studies in the 1950s and 1960s (e.g. Borsky, 1954; McKennell, 1963; Sörensen et al., 1973; DFG, 1974). Several reviews, re-analyses and meta-analyses of the impact of non-acoustic factors have been carried out (Fields, 1993; Guski, 1999; Miedema & Vos, 1999; Vader, 2007; Sanchez et al., 2015; Haubrich et al., 2019).

In the literature, there are currently two main scientific views on how a non-acoustic factor could affect annoyance related to noise:

1. *Majority scientific view*: a non-acoustic factor affects annoyance without being a noise response itself[1]
2. *Minority scientific view*: a non-acoustic factor affects annoyance by being part of the causal chain from noise exposure to annoyance; i.e., it can act as an intervening variable[2]

In the rest of this document, the "majority scientific" view of professionals who study noise will be used to define non-acoustic factors of community noise annoyance; i.e., non-acoustic factors are contextual and personal factors that modify annoyance judgments without themselves being part of the primary noise response mediating or triggering the effect of noise on annoyance.

2.2 Understanding non-acoustic factors requires understanding annoyance

Understanding the role of non-acoustic factors in noise annoyance requires an understanding of the concept of annoyance. In the WHO evidence review on environmental noise that informed, among others, the WHO Environmental Noise Guidelines (WHO, 2018), noise annoyance is defined as a multi-faceted concept including the following elements (Guski et al., 2017):

(1) an often repeated disturbance due to noise

(2) an emotional/attitudinal response (e.g. anger, dissatisfaction) and

(3) perceived (lack of) control or (in-)capacity to cope with the noise situation (i.e. "the distressful insight that one cannot do much against this unwanted situation", Guski et al., 2017, p. 2)

The multi-faceted conceptualization of annoyance is quite similar to the definition of psychological stress, which occurs "when an individual perceives that environmental demands tax or exceed his or her adaptive capacity" (Cohen et al., 2007, p. 1685).

For the understanding of non-acoustic factors of annoyance, it is important to recognize that annoyance is not restricted to the pure judgment of the sound of a noise event, but an evaluation of the whole situation in which one or more noise events occur.

There are two sides of the coin leading to psychological stress as reflected in the judgment of annoyance:

[1] See, for example, Fields (1993), Lercher (1996), Guski (1999) and Flindell et al. (2021).
[2] See, for example, Wirth (2004) and Bartels et al. (2015).

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1. the extent of the stressor ‘noise’ over a period of time, for example in terms of intensity (level), number and/or duration of noise events, and
2. the extent of individually perceived available resources for ‘managing’, i.e. coping with, the noise situation (Stallen, 1999).

A third aspect is the possibility of restoration. The adaptive resources needed to cope with environmental stress require periodic restoration, i.e. the process through which diminishing coping capacities are renewed (Hartig, 2004). Some types of environmental settings such as the natural environment or urban green space are regarded as having restorative quality (Hartig, 2007), which in fact may reduce noise annoyance (Gidlöf-Gunnarsson & Öhrström, 2007; Dzhambov et al., 2018; Van Renterghem, 2019).

This is where non-acoustic factors come into play. Whereas acoustic factors such as sound levels or the number of events above a threshold (*N*x) affect the perceived demanding level of the environmental stressor (‘noise’), non-acoustic factors in particular add to the explanation of annoyance when they affect the actual and/or perceived resources to cope with the noise situation and their renewal (restoration) (Schreckenberg et al., 2018).

The perception of having resources to cope with noise can be understood as being similar to perceived control, which is regarded as a key factor of noise responses (Glass & Singer, 1972; Hatfield et al., 2002; Kroesen et al., 2008; Schreckenberg et al., 2018) and psychological stress in general (Baum et al., 1981; Compas et al., 1991). Therefore, person- and situation-related non-acoustic factors that facilitate or hamper perceived control and the capacity to cope with noise are particularly important for noise annoyance (Stallen, 1999).

For example, the personal disposition of ‘noise sensitivity’ increases the susceptibility to noise in general and affects the reactions to noise, while being independent from noise exposure. It correlates stronger with the perceived lack of capacity to cope with noise than with judgments of transportation noise annoyance and disturbances (Schreckenberg et al., 2018). The same is true for attitudes such as residents’ trust in authorities regarding aviation and road traffic authorities and industry (Schreckenberg et al., 2018). Also, the observed elevation of responses to aircraft noise (so-called change-effect), e.g. after the opening of a new runway, is stronger for the perceived lack of coping capacity than for disturbances of activities due to aircraft noise (Schreckenberg et al., 2019). Similarly, the beneficial effect of access to green areas at first is that the restorative quality of such areas allows to renew the coping capacities (Hartig, 2004) and would probably marginally lead to changes in perceived disturbances of the noise exposure that is still present (Föllmer et al., 2020).

In a noise situation, residents can have immediate direct control over a noise situation by closing windows or accessing respite locations and periods. Indirect control would mean to perceive being represented in noise-related decision-making processes and, thereby, having voice either personally or through trusted authorities that act and decide on the residents’ behalf (Van Kamp et al., 2019).

In that sense, it is important to distinguish long-term from short-term coping strategies in the same way that we differentiate between long-term and short-term annoyance. Short-term coping strategies can strongly influence the discomfort felt in a specific situation. In contrast, long-term coping strategies can on the long run affect residents' health. Non-acoustic factors play a different role hereby. For example, European studies show that those residents reporting to usually have the bed-room window closed at night-time in warm seasons report higher long-term sleep disturbances and long-term nocturnal noise annoyance than those usually having the window open or half-open. This is a finding related to aircraft noise (Schreckenberg, 2012) but also to other sources, e.g. railway noise (Schreckenberg, 2013). From an acoustical point of view, one would expect that those with

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half-open or open windows are more annoyed due to higher noise levels indoor from outdoor noise sources. In fact, this is true for short-term aircraft noise annoyance as assessed with the experience-sampling method (e.g. Schreckenberg & Schuemer, 2010). However, on a long-term level, being forced to have windows closed because of the noise from outside is in itself one of the strongest noise-related disturbance (Öhrström et al., 2006). It seems that the situational factor 'window position' is actually a non-acoustic one, as it seems to refer more to perceived control and coping (one is forced to close the window, i.e. it is perceived as externally controlled) and less to the loudness and disturbing effect of the incoming sound from outside itself.

As described above, control over the noise situation or aviation-related decisions can strengthen one's coping capacity.

2.3 Categorization of non-acoustic factors

Several authors have suggested categorizations of non-acoustic factors.

- Fields (1993): Personal and situational variables
- Lercher (1996): Personal and attitudinal moderating variables vs. contextual moderating variables
- Bartels et al. (2015): Personal, social, and situational factors
- Van Kamp & van den Berg (2018): Contextual and personal factors subdivided into situational factors, demographic and socio-economic factors, personal factors, and social factors

Some authors focus on personal and social factors when talking about non-acoustic factors:

- Guski (1999): Personal and social co-determinants (not discussing situational variables)
- Miedema & Vos (1999): demographic and attitudinal factors

Others focus on situational factors, for example:

- Access to green space (Van Renterghem, 2019; Gidlöf-Gunnarsson & Öhrström, 2007; Dzhambov et al., 2019; Schäffer et al., 2020)
- Availability of quiet areas within a building[3]: de Kluizenaar et al. (2013), Amundsen et al., 2011; Van Renterghem & Botteldooren (2012)

With focus on different types of noise interventions, van Kamp et al. (2019) refer to factors that affect noise responses or noise-related health outcomes in terms of

- "other physical interventions", not directly related to the noise source and the sound transmission to the recipient, including the improvement of the acoustic quality of the outdoor environment as perceived by people (soundscape) and
- education / communication in order to change attitudes, improve coping capacity, explain reasons of noise (interventions), inform about noise source in order to influence perception regarding the sources.

Some authors plotted or cross-tabulated the strength of the impact of a non-acoustic factor on noise responses or importance in explaining annoyance with the modifiability of the factor – all of them in

[3] See European research on quiet façade.

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the context of aircraft noise annoyance (Vader, 2007; Sanchez et al., 2015, Asensio et al., 2017; Haubrich et al., 2019).

However, whereas the strength of the impact of a non-acoustic factor on noise responses can be partly derived from empirical studies of effect size, the modifiability (e.g. by aircraft noise management) is a somewhat arbitrary setting lacking empirical foundation.

Researchers of the ANIMA project started with reviewing the research on non-acoustic factors with the focus on recommendations for aircraft noise management (Haubrich et al., 2019) but revised and enhanced this way of categorising non-acoustic factors by adding the evaluation of the effect of non-acoustic factors on sleep disturbances, introducing the criterion of 'addressability' of the non-acoustic factor and giving examples of how the listed non-acoustic factors could be addressed (Bartels et al., 2020, in print). The addressability was introduced in order to also consider non-acoustic factors that can hardly be modified by a third party per se but that can be taken into account when planning noise interventions. For example, age cannot be changed but can be addressed in land-use planning in airport region when placing locations for vulnerable age groups (for children: placing kindergarten, schools; for elderly: placing nursing homes) (Bartels et al., 2020, in print, Table 1).

For the purpose of this paper, the following distinction of non-acoustic factors is proposed:

- internal personal factors including demographics, personal traits (e.g. noise sensitivity), attitudes
- external social factors such as (social) media coverage, social cohesion
- external physical factors, e.g. green or blue space

3 Consensus science studies on non-acoustic factors

3.1 Summary from CAEP11 noise impacts white paper

Chapter 2 from the noise impacts white paper (Sparrow et al., 2019) focused on community noise. There were many aspects of that document that point out the importance of non-acoustic factors in assessing annoyance due to aircraft noise. In section 2.3 the noise impacts white paper points out the importance of the rate of change with respect to noise and provides the example of a new runway being opened. It continues with an important text on the subject:

"Since airports and communities may differ greatly with respect to acoustic and non-acoustic variables, local exposure–response relationships, if available, may be preferred for predicting annoyance and describing the noise situation with desired accuracy. Still, generalized exposure–response relationships are desirable to allow assessment across communities and to establish recommended limit values for levels of aircraft noise."

Section 2.4 of the report contains two paragraphs on non-acoustic factors that are repeated here to highlight several important points:

"Two old meta-analyses on the influence of non-acoustic factors on annoyance (Fields, 1993; Miedema & Vos, 1999) showed the factors of fear of danger of aircraft operations, followed by noise sensitivity and age, had the largest effects. More recent results indicate that fear is no longer a dominating modifying factor. Other important modifying factors may be distrust in authorities and

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expectations of property devaluation (Schreckenberg, et a., 2017). Guski et al. suggested (Guski, et al, 2017) that the rate of change at an airport with respect to noise and operational procedures could be an important moderating factor. They defined two types: Low-Rate-of-Change (LRC) and High-Rate-of-Change (HRC), airports. Gelderblom et al. have shown that the average difference in the annoyance response between these two types of airports, LRC and HRC, corresponds to a 9-dB-difference (9 dB ± 4 dB) in the noise exposure (Gelderblom et al., 2017). Guski et al. reported a similar, but smaller difference, about 6 dB (Guski et al., 2017). The difference between the two studies is likely due to different selections and weighting of survey samples."

"An important non-acoustic factor seems to be the attitude towards the noise source and/or its owner. Contrary to common beliefs, people that benefit from the air traffic are not more tolerant to aircraft noise (Flindell & Witter, 1999). A lack of trust in the authorities, misfeasance, and a feeling of not being fairly treated will increase the annoyance (Schreckenberg, et al., 2017). People may adapt different coping strategies, i.e. to master, minimize or tolerate the noise situation. Noise sensitive people have more difficulties coping with noise than others (Job, 1999). If the respondents in a survey are selected according to proper random procedures, and the number of respondents is large enough to be an accurate representation of the population, individual factors will have the same effect in all surveys. However, other factors are location specific, for instance number of aircraft movements, prevalence of night time operations, LRC/HRC categorization, etc. The survey results from different airports will therefore vary unless these location specific factors are the same, or that they are accounted for statistically. Hence the search for a common exposure-response function, a 'one curve fits all' solution, may not be applicable for all purposes."

The noise impacts white paper goes on to say in Section 2.6 that "The observed influence on annoyance of personal non-acoustic factors such as perceived control, and trust in authorities suggests that communication strategies addressing these issues could contribute to the reduction of annoyance, alongside or even in the absence of a noise reduction." In its conclusions, the white paper states "Location and/or situation specific acoustic and non-acoustic factors play a significant role and must be taken into account."

3.2 Summary from ANIMA D2.4 - Recommendations on annoyance mitigation and implications for communication and engagement (Ch. 7)

A systematic literature review with respect to the role of non-acoustic factors in noise impact mitigation interventions was done by Haubrich et al. (2019) within the European ANIMA project. Non-acoustic factors are defined as aspects that are not related to the sound itself in a direct manner (Asensio et al., 2017). Haubrich et al. (2019) built upon Vader's (2007) categorization of non-acoustic factors regarding the factors' modifiability and strength (i.e. their influence on noise annoyance). These non-acoustic factors include, for example, attitudes, perceived control, trust, perceived fairness, avoidability, and the predictability of the noise situation (Vader, 2007). According to Vader (2007), non-acoustic factors such as attitudes to the noise source, trust and perceived control have the strongest influence on people's annoyance levels and are the most modifiable within the scope of interventions.

The review by Haubrich et al. (2019) further states that these attitudinal non-acoustic factors can be best addressed by a certain category of interventions: communication with and engagement of relevant stakeholders such as residents. Public participation is a long and widely known concept. Engaging people to solve a common and shared issue, which is also known as social learning (Webler

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et al., 1995), can, for example, positively affect perceived control (having a voice). This involvement in the decision-making process can foster decisions that are viewed as fairer (Asensio et al., 2017). The two key elements of social learning are moral development (focusing on societal instead of personal benefits) and cognitive enhancement (acquiring knowledge; Webler et al., 1995).

Further, the concepts of *fairness* and *competence* are viewed as relevant aspects of engagement processes and can influence trust in authorities. *Fairness* is present, when people are viewed and treated equally, a sovereignty of the public as well as individual competence can develop (Webler, 1995). A participation process should equip participants with the proper tools and knowledge required for choosing the best possible option (Petts, 1999), i.e. foster *competence*.

The ANIMA resumes that knowing the link and interplay between different non-acoustic factors can help developing suitable interventions to decrease noise annoyance.

3.3 U.K. Survey of Noise Attitudes Non-Acoustic Factors

The U.K. Survey of Noise Attitudes (Rhodes et al., 2017), commissioned by the UK Department for Transport, obtained information on attitudes to aircraft noise from 2,000 people around nine U.K. airports in 2014. The work was independently peer reviewed, with the peer review published alongside the study report. As well as obtaining up to date information on annoyance from aircraft noise, the survey also sought information on a range of non-acoustic factors. Regarding personal non-acoustic factors, self-reported noise sensitivity was found to be strongly correlated with the likelihood of being highly annoyed, with the most sensitive persons being just over three times as likely to be highly annoyed than the median noise sensitivity rating, and the least sensitive rating being one third as likely to be highly annoyed compared with the median noise sensitivity rating. Gender was not found to be statistically significant, whilst age was found to be statistically significant with 55-64 and 65-74 year olds found to be 2.7 and 2.6 times more likely to be highly annoyed than the median 35-44 age group.

Length of residence was found to have a significant association with annoyance only for residence of 1-2 years and 2-5 years respectively. Compared to the median group (more than 10 years resident), residents in both age groups were found to be around half as likely to be highly annoyed.

Socio-economic status was strongly correlated with being highly annoyed, with the likelihood of being highly annoyed increasing with increasing socio-economic status.

Regarding expectations of hearing noise from the airport prior to moving, those that said the noise was less than expected were less than half as likely to be highly annoyed as the reference group that that thought the noise was roughly what they expected. Those that thought the noise was more than they expected were 8.6 times more likely to be highly annoyed, and those that thought it had gotten worse since they had moved were 19 times more likely to be highly annoyed.

Regarding expectations of noise next summer, 68% of residents surveyed said they expected to the noise to be about the same. Those that thought the noise would be less than currently, indicated they were less than half as likely to be highly annoyed. In contrast those that thought the noise would be more next summer were 4 to 10 times as likely to be highly annoyed.

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3.4 Neighborhood Environmental Survey Results Related to Non-Acoustic Factors

The Federal Aviation Administration (FAA) has undertaken a multi-year research effort to quantify the impacts of aircraft noise exposure on communities around airports in the United States (US) through the Neighborhood Environmental Survey (NES)[4]. The goal of the study was to produce an updated and nationally representative civil aircraft dose-response curve providing the relationship between aircraft noise exposure and annoyance. Note that while consideration of non-acoustic factors was not directly included in the NES methodology, supplemental analyses considered how a range of factors may correlate with the annoyance to aircraft noise may provide targeted insight on non-acoustic factors.

The NES utilized multiple independent reviews: statistical analysis methodologies were approved by the U.S. Department of Transportation Bureau of Transportation Statistics (BTS) and data collection was approved by the Office of Information and Regulatory Affairs a statutory part of the U.S. Executive Office of Management and Budget; the statistical and survey team's Institutional Review Board[5] also reviewed all of the methodologies used in conducting the national survey; technical peer reviews included the Federal Interagency Committee on Aviation Noise (FICAN) as well as external review groups that examined the methods underlying the data collection and analysis process and the resulting data.

Balanced sampling was used to select the 20 airports for the NES, with the goal of obtaining a representative sample of US airports. More than 10,000 Households around these airports participated in the survey. Two survey instruments were administered to adult residents within the NES: a primary mail questionnaire and a follow-up telephone interview. The updated U.S. National Dose-Response curve was derived from the results of the mail survey; participating respondents were then invited to the participate in a telephone interview, which asked detailed questions to better understand factors influencing annoyance.

The survey team completed 2,328 telephone interviews and the FAA's research team has conducted a preliminary evaluation of the telephone survey results. From the wide range of topics covered in the telephone questionnaire, the scope of the analysis was designed to provide a thorough, but not necessarily exhaustive, review of the information. Future research on this data may provide additional insights, including how non-acoustic factors should be defined and what role they may play in better understanding annoyance from aircraft noise exposure.

From the phone survey response, three exploratory analyses were conducted: (1) Comparison with mail survey results, (2) Exploratory factor analysis (EFA), and (3) Characteristics of highly and not-highly annoyed respondents.

(1) Comparison of telephone dose-response curve to the mail survey results. The dose-response curve generated from the telephone survey indicates less highly annoyed responses versus the mail survey. Three hypotheses were suggested to explain the difference in reported percent highly annoyed across survey modes. The best explanation was that of social desirability bias of the telephone survey, i.e., people responded differently when the survey was interviewer-administered (telephone) versus self-administered (mail).

[4] Analysis of the Neighborhood Environmental Survey, 2021: https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/ArtMID/3682/ArticleID/2845/Analysis-of-NES

[5] IRB00000695 - Westat, Inc. IRB: Issued by the United States Department of Health & Human Services, Office for Human Research Protections

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(2) *Exploratory factor analysis (EFA).* EFA is a statistical technique to find one or more groups of variables, called "factors", which summarize complex inter-relationships of observed variables. For the telephone survey, an EFA was conducted to better understand the relationship of the answers given by the respondents to their annoyance from aircraft noise. The EFA identified seven factors. Interpreting the top-ranked factor, Factor 7, as an example, people's degree of being highly annoyed by aircraft noise correlated to their degree of being startled, frightened and/or awakened by aircraft noise. Twenty-two questions had weak connections with other questions in the survey and could not be grouped into factors, but when comparing their overall strengths of association with the survey's focus question to the Factors' strengths, five of the 7 factors, i.e., Factors 7, 3, 4, 2 and 1, ranked higher than these 22 questions. As shown in Table 1, Factors 5 and 6 were outranked by three of the ungrouped questions in terms of their importance to aircraft noise annoyance. The strength of association with the survey's focus question was also examined across four DNL stratum, for each of the factors and remaining questions. Factors 3 and 7 were consistently ranked first or second across all of the DNL strata. That is, the correlation of aircraft noise annoyance with being startled/frightened/awakened and their general traffic noise/smells rating were stronger than all other factors/questions, regardless of DNL.

(3) *Characteristics of highly and not-highly annoyed respondents.* Another type of statistical analysis, called a Classification and Regression Tree (CART) analysis, was undertaken to identify characteristics of highly and not-highly annoyed respondents in the four DNL strata of interest. In all DNL strata, the most important characteristic for predicting highly annoyed respondents is being startled, frightened, or awakened by aircraft noise. The next most important characteristic for predicting highly annoyed respondents is the belief that the airport is not working collaboratively with them, however, this was limited to the 50-55 dB DNL and 60-65 dB DNL strata.

Table 1. Ranking Factors and Questions by DNL Stratum

Factor	Question No.	Variable Name	Factor Theme or Survey Question	Pseudo R-Square Values (with rank of top 8)				
					DNL Stratum (dB)			
				Overall	50-55	55-60	60-65	65+
F7			Startle, Frighten or Awaken	0.373 (1)	0.319 (1)	0.377 (1)	0.348 (1)	0.300 (2)
F3			General traffic noise/smells rating	0.247 (2)	0.201 (2)	0.239 (2)	0.273 (2)	0.314 (1)
F4			Safety concerns	0.175 (3)	0.148 (4)	0.109 (7)	0.177 (5)	0.150 (8)
F2			Airport effort to deal with aircraft noise	0.170 (4)	0.148 (5)	0.165 (3)	0.166 (6)	0.179 (6)
F1			Concerns or complaints with neighborhood	0.153 (5)	0.124 (8)	0.139 (4)	0.187 (3)	0.186 (5)
n/a	39	PACPctFlyOverHCAT	Thinking about all the aircraft you notice when you are at home, about **what percent fly directly over your property?**	0.152 (6)	0.156 (3)	0.134 (5)	0.132 (7)	0.217 (3)
n/a	23	PNbrsViewACNse (1)	How about your **closest neighbors making their views known about aircraft noise:** Have they clearly made their views known, have they revealed only a little about their views, or have they kept their views to themselves?	0.150 (7)	0.129 (6)	0.132 (6)	0.179 (4)	0.188 (4)
n/a	14	PACNseChg	Since you moved here, has the total **amount of aircraft noise increased, decreased or stayed about the same?**	0.118 (8)	0.128 (7)	0.090 (7)	0.125 (8)	0.164 (7)
n/a	44	PDangerTrf	Which type of **traffic, if any, do you feel is the most dangerous for you or your property** when you are here at home: road traffic, railway trains or aircraft?	0.095	0.097	0.045	0.115	0.120
n/a	15	PACNseFuture (1)	What do you think **aircraft noise will be like here in the next few years:** Do you think the total amount of aircraft noise will increase, decrease or stay about the same here?	0.092	0.095	0.066	0.103	0.128
F5			Knowledge of aircraft noise issues	0.066	0.063	0.041	0.044	0.104
n/a	36	PRespSenstve	How **sensitive are you generally to noise** of all kinds: extremely sensitive, very sensitive, moderately sensitive, slightly sensitive, or not at all sensitive?	0.057	0.075	0.078	0.070	0.097
n/a	24	PAuthDisputes (1)	As far as you know, have there ever been **disputes between airport authorities and community residents about aircraft noise** around <AIRPORT>? y/n	0.043	0.023	0.054	0.059	0.081
n/a	38	PACTakeOffLand (1)	Are most of the aircraft that you notice from your home **coming down for a landing at the airport, taking off from the airport, are about half landing and about half taking off, are they doing something else, or don't you know?**	0.031	0.041	0.056	0.039	0.071
n/a	42	PCNTrfAccdnt	When you are at home or around the neighborhood, **how fearful or concerned are you that there might be car or truck road traffic accidents nearby:** Are you extremely, moderately, slightly, or not at all concerned that there might be a road traffic crash?	0.029	0.058	0.045	0.058	0.110
n/a	34	PAPRedACNse (1)	How fully do you feel the <AIRPORT> officials **keep community residents informed about the planning for airport changes?** Do you think the officials keep communities extremely well informed, very well informed, moderately well informed, slightly informed, or not at all informed?	0.028	0.025	0.048	0.051	0.064

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As shown in Table 1, respondents who reported being “startled, frightened, or awakened” by aircraft noise were most highly correlated with their reported level of annoyance. This was followed by respondents who reported being concerned with “general traffic noises or smells” in their neighborhood. Correlations with annoyance by these two factors were substantially higher than all other factors, including the factors which could broadly be interpreted as non-acoustic in nature. While the analysis of the NES phone survey is only preliminary and warrants further assessment, these results do appear to indicate that the acoustic or acoustically induced factors are the primary drivers of annoyance. Additional research is still needed to understand the appropriate definition and categorization of non-acoustic factors as well as any interdependencies between acoustic and non-acoustic factors.

4 Conclusions

Our awareness that factors, not related to sound levels, can have an impact on how communities react to noise has existed for decades. But only recently has the topic come out of the background, and our knowledge base is growing. From the CAEP/11 white paper on aviation noise impacts there is a consensus that non-acoustical factors could prove useful in examining community response to noise. While the results from the U.S. FAA study is inconclusive, the study from the U.K. CAA indicates non-acoustic factors are almost certainly showing up in community surveys of aircraft noise. The ANIMA report pulls many analyses together, but its limitation is that it is almost exclusively focused on studies conducted and reported in Europe. Due to differences in cultures, expectations, as well as city and building construction, it is unclear if the results are generalizable to communities worldwide.

Much more work will be needed to better understand these regional differences. For example, cross-cultural noise assessments could be conducted to see if the ANIMA approaches would be implementable and effective globally. With additional work, the scientific community could determine the relative importance of acoustic and non-acoustic factors, potentially providing decision-makers with more effective tools to address community noise concerns.

One recent development, which could facilitate future research, is the implementation of an ISO specification for non-acoustic factors (Fenech et al., 2021). According to Fenech et al. (2021), an ISO standard would allow the merging of research data from different studies. This would facilitate the evaluation of the measuring instruments, and, ultimately, the identification of effective interventions targeting non-acoustic factors.

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