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FOUNDATIONS FOR A COMPREHENSIVE APPROACH OF ACOUSTIC AND NON-ACOUSTIC MEASURES OF AIRCRAFT NOISE ANNOYANCE MITIGATION

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ABSTRACT:

This contribution presents the construct of aircraft noise annoyance and its acoustic and non-acoustic contributory factors. It draws upon key findings of a review that was produced within the frame of the EU Horizon 2020 funded research project *Aviation Noise Impact Management through Novel Approaches* (ANIMA). It is shown that aircraft noise annoyance can be seen as a psychological stress response. This is in line with empirical findings, according to which a) only approx. 30% of noise annoyance can be explained with acoustic parameters, and b) there are a number of non-acoustic factors affecting annoyance. Different non-acoustic factors are presented. They result in implications and recommendations for noise management strategies, which are discussed in more detail in contribution #137 of the Aerospace Europe Conference 2020 [1].

1. RELEVANCE AND IMPACT

In the ongoing research project *Aviation Noise Impact Management through Novel Approaches* (ANIMA) by the Horizon 2020 Research and Innovation Program of the European Union, new scientific, political and (aviation) management methods and tools are developed, evaluated and made available to actors at all levels by an interdisciplinary and international research team. In particular, two goals are aimed at: "the capacity of the Union to ensure the highest environmental standards of well-being and living conditions for EU citizens and the EU global leadership on industries and services for mobility and air transport" [2]. Further information on this project can be found on the project homepage at https://anima-project.eu.

In this contribution, the results of a Deliverable [3] are presented, in which the current status and recommendations on annoyance mitigation were developed as part of several reviews. This also results in implications for communication and engagement, which are addressed in another contribution to this conference [1].

Noise annoyance is one of the most prominent community responses to aircraft noise. In the WHO Environmental Noise Guidelines [4], annoyance is considered one of the 'critical' health outcomes, alongside sleep disturbances, cardiovascular diseases, and others. According to the WHO Constitution, health is "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity" [5], so that (long-term) annoyance per se is considered as a health outcome. In addition, particular importance arises from evidence that annoyance can promote and intensify the occurrence of other negative health outcomes [6].

Apart from the health impacts, further relevance for noise annoyance results from the fact that aircraft noise annoyance is a strong negative predictor of cooperative behaviour of residents in airport regions and a strong predictor of the quality of the relationship between airports and their communities as well as of the 'licence to grow' for airports granted by residents. In addition to the costs that annoyance of residents can incur for airports - for example, because of delays or restrictions due to protests about planned airport extensions - annoyance of residents in airport areas also causes welfare loss costs that rise with increasing aircraft noise exposure. According to current calculations, the valuation of the price of noise annoyance in the EU ranged in 2016 from EUR 34 (per person and year in residential areas with an average aviation noise exposure of Lden 50-55dB) to EUR 129 (in areas with an average exposure of Lden > 65dB) [7].

2. AIRCRAFT NOISE ANNOYANCE

2.1. Definition

Noise is unwanted sound and contains an evaluation of the sound source, which can be either conscious or unconscious.

Noise annoyance is a widespread and much-studied concept in the scientific literature. Reference [8] carried out a comprehensive review of the existing definitions of noise annoyance and additionally interviewed international noise impact researchers on definitions of noise annoyance. On this basis, they developed a comprehensive and coherent definition, which they updated in their WHO review on environmental noise and annoyance [9]. Accordingly, environmental noise annoyance is understood as:

"…a retrospective judgment, comprising past experiences with a noise source over a certain time period. The noise annoyance response usually contains three elements:

1. an often repeated disturbance due to noise (repeated disturbance of intended activities, e.g., communicating with other persons, listening to music or watching TV, reading, working, sleeping), and often combined with behavioral responses in order to minimize disturbances;

2. an emotional/attitudinal response (anger about the exposure and negative evaluation of the noise source); and

3. a cognitive response (e.g., the distressful insight that one cannot do much against this unwanted situation).

This multi-faceted response is seen by many researchers as a stress-reaction" [9].

In our review it was found that this definition is by far the most frequently cited one in the relevant research literature and therefore can be regarded as generally accepted. Of particular relevance is the realization that noise annoyance is a *multidimensional* construct that is located on the behavioural as well as on the cognitive and the emotional level. This implies several ways of influencing - or, to put it another way, it also implies several factors on which attempts to influence can fail. Furthermore, the definition shows overlaps with classic psychological stress reactions, which are examined in more detail in the next section.

2.2. Stress response

The complex, multifaceted nature of noise annoyance, comprising behavioural, attitudinal-affective-emotional, and cognitive elements, shows resemblances to the transactional model of stress and coping, developed by Lazarus [10]. A summary of the general stress model according to Lazarus is depicted in Figure 1.

Many studies [e.g., 11, 12]. have shown that noise annoyance itself can be understood as a psychological stress reaction. Stress in general - and noise as an environmental stressor as well - is

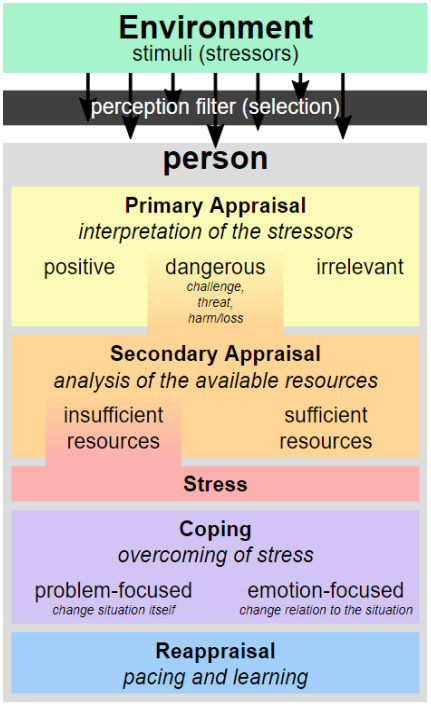

Figure 1: Transactional model of stress and coping by Lazarus

the result of an interaction between environmental and personal factors. Special importance is attached to the subjective evaluation of both the stressor and a person's individual resources. If the available resources are rated as insufficient for the given stressor - or, in other words, if an environmental demand exceeds the capacity of an individual to cope with it - a stress response is triggered [12]. Stress, in turn, provokes coping processes to reduce stress. The level of stress depends on the perceived controllability or predictability of the situation. That is, the level of subjective stress or annoyance depends not only on the nature and magnitude of the particular stressor or, in the case of noise annoyance, not only on the specific level, duration or frequency of aircraft noise exposure. Contextual and intrapersonal factors that affect the capacity of residents to cope with the noise situation also play a role.

This finding is in line with findings from noise annoyance research:

- For example, it is known that only up to 30% of noise annoyance can be explained by average

sound levels [9].

- Further, there is the widely observed finding that a reduction in aircraft noise *exposure* is not accompanied by the reduction of aircraft noise *annoyance* to the extent that would be expected based on exposure-response curves.

- This is also shown, among other things, by the fact that despite decreasing average aircraft noise exposure over the years, the average measured aircraft noise annoyance of residents did not decrease proportionately over the same period.

Altogether, this allows the conclusion that the actual magnitude of aircraft noise annoyance is influenced by more than just exposure-related, acoustic factors. Therefore, for an effective reduction of aircraft noise annoyance, non-acoustic factors or contributors must be taken into account, too - approaches that rely on a reduction of noise exposure alone do not exploit the full scope of possibilities.

3. CONTRIBUTORS TO NOISE ANNOYANCE

3.1. Acoustic factors

Acoustic factors related to aircraft noise annoyance include in particular aircraft noise exposure with all of its sound-related characteristics; that is above all the sound level, but also features such as the frequency and the duration of noise exposure.

There are a variety of different acoustic measures representing one or a combination of several of these features. When specifying average values over a longer period of time, the characteristics of single events must be offset against each other. There are a large number of standardized measures for this (e.g. continuous and rating sound levels such as L_{Aeq}, L_{dn}, L_{den}), but they always necessarily summarize reality in a simplified manner. Some measures are also subject to more or less arbitrary weightings, e.g. "punishments" or special weightings for nocturnal aircraft noise. An example for this the day-evening-night level L_{den} used in noise mapping according to the European Environmental Noise Directive 2002/49/EC [13], which included a penalty of 5 dB for noise exposure in the evening and of 10 dB for noise exposure in the night.

Specific values of a measure can originate from different realities and, especially for residents, the connection between a quantity number and their subjectively perceived exposure is often hard to comprehend.

A comprehensive compilation of different acoustic measures that are relevant for aircraft noise -- ranging from standard metrics for single events like the A-frequency weighed L_{Amax}, to standard long-term averaged metrics like the L_{Aeq} and the L_{den}, weighted L_{eq}-type metrics, up to perceived noise level metrics and alternative acoustic metrics – is given in [3].

3.2. Non-acoustic factors

Both empirical findings, as well as the theoretical model explaining noise annoyance in terms of a classical psychological stress response, show that the acoustic features of noise only explain a (rather small, i.e. around 30%) part of the annoyance response to aircraft noise and that non-acoustic characteristics of the person or the environment also have a decisive contribution.

As part of our systematic review, we showed that in recent years the influence of non-acoustic factors on the extent of aircraft noise annoyance received increasing attention in aircraft noise annoyance studies.

Non-acoustic factors are defined as those “which are not directly connected to the nature of the sound“ in [14]. These can be personal characteristics and traits, social factors, as well as environmental or situational factors. In 2007, [15] identified 31 non-acoustic factors known to affect noise annoyance as part of a comprehensive review. They categorized them in individual and situational factors and arranged them along 2 dimensions:

1. their strength or ‘importance’ as a factor in explaining annoyance, i.e., the magnitude of their influence on annoyance (using the categories strong/high, intermediate/mix, and weak/low);

2. the extent of their modifiability by aircraft authorities, which reflects their usability as an instrument (using the categories modifiable and not modifiable).

Many authors have joined this conceptualization [see 14]. For example, [15] examined a number of non-acoustic factors and located them according to this scheme – based on empirical findings – as depicted in Figure 2.

Of particular importance for noise annoyance management strategies are those factors that are principally modifiable (other than for example gender or age) and at the same time make an important contribution in explaining aircraft noise annoyance. These can be seen in Figure 2 in the upper right area within the circle.

It turns out that these particularly relevant non-acoustic factors are strongly connected with the stress model of noise annoyance. For some, the connections are particularly obvious because they are directly or indirectly associated with the extent of the perceived noise exposure, for example, "satisfaction with insulation" and "interference with activities". It can be assumed that these factors are, in the stress model, linked to the first level and to a reduced stressor and are therefore related to a lower annoyance.

4. CONCLUSIONS AND OUTLOOK

In this paper, it was shown that aircraft noise annoyance can be conceptualized as a classic psychological stress reaction and that it is influenced to a large extent by non-acoustic factors. It was also demonstrated that some of the particularly important non-acoustic factors can be addressed with noise management strategies. In the related contribution #137 [1] from the same EU project, various consequential recommendations

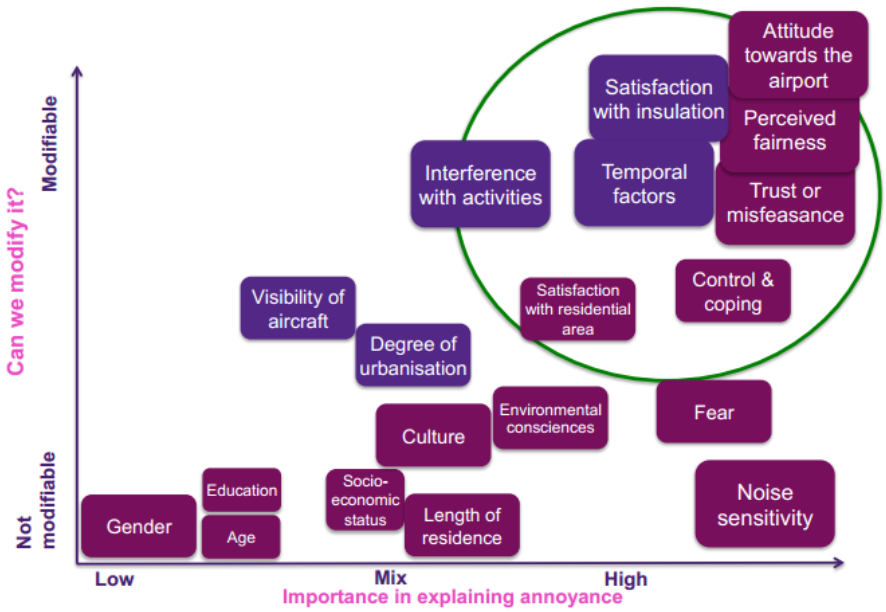

Figure 2: Non-acoustic factors, arranged according to their importance in explaining annoyance and their modifiability [Source: Anderson Acoustics; Figure taken from 15]

Other particularly relevant non-acoustic factors are located at a lower level of the stress model. Various studies show that the personality-related factors "trust (or misfeasance)", "control (& coping)", "perceived fairness", and "attitude towards the [noise source]" influence the interpretation and the 'primary appraisal 'of aircraft noise as an environmental stressor. Above all, a high degree of 'trust' and 'fairness' go hand in hand with reduced annoyance values. In this context, this means, for example, an understanding of the reasons why an airport operates the way it does, and the perception that personal, resident-related interests and needs are acknowledged and taken into account in the decisions. A strong predictor of lower annoyance is also controllability, which essentially means the opposite of feeling delivered. Therefore, a large part
of controllability in this context is determined by predictability. This means that the knowledge about when and for how long which type of aircraft noise is to be expected strengthens the feeling of controllability and lowers the annoyance.

for information management, engagement and communication strategies are elaborated and linked to possible intertwines and extensions of the “Balanced Approach to Noise Management” by the International Civil Aviation Organization (ICAO).

One issue that has not been empirically investigated is how residents may react if actions to address their annoyance are tackled with non-acoustic means. Some difficulties are conceivable here, which are examined as part of further upcoming and ongoing studies of the ANIMA project.

5. ACKNOWLEDGEMENT

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