PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Noise Annoyance: What does it mean?

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EXTENDED ABSTRACT

Keywords: Noise, Annoyance, Community, Management

1. INTRODUCTION

The acoustics community has struggled for many years to find a completely acceptable assessment of noise annoyance. Following a long history of research using alternative definitions and assessments of the concept, a concerted international effort eventually resulted in standardized definitions. These were first published in 2001 by the International Commission on Biological Effects of Noise (ICBEN)[1] and were then adopted as an international technical specification ISO/TS 15666:2003(E) on the assessment of noise annoyance in social surveys[2] (last reviewed and confirmed in 2017).

They were designed to overcome the previous huge variety of inconsistent and incompatible annoyance scales. Previously, there was only limited or no comparability between the results of different studies using different scales[3].

The ICBEN question for the assessment of noise-induced annoyance, available in 9 languages in the original version, is as follows. The ICBEN offers 2 different answer scales to this question, which can be queried separately or together in a survey (ICBEN recommends to use both scales because there was no consensus as to which was 'best'):

- A 5-point verbal scale, recommended for contexts of communication with policy makers:

  "Thinking about the last (… 12 months or so…), when you are here at home, how much does noise from (… noise source…) bother, disturb, or annoy you?"
  "extremely", "very", "moderately", "slightly", and "not at all"[1] .

- An 11-point numeric scale, recommended for research purposes, as it is suitable for multivariate statistical methods:

  "Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero and ten. Thinking about the last (..12 months or so..), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (..source..) noise?" [1].

Probably the main justification for developing these standard annoyance scales was the problem of comparing the results of different surveys where people had been asked to report their response to community and environmental noise, but in different ways and with different wordings in questionnaires, and this is notwithstanding uncertainties arising from questionnaires written and administered in different languages. Previous to the widespread introduction of standardised measurement scales, various attempts to devise common, 'harmonised', dose or exposure – response relationships had all been subject to effectively unknown degrees of uncertainty in terms of the measurement of both noise exposure and individual response to that exposure. It was anticipated that by using standardised response scales as above, at least one source of uncertainty could be removed.

The present authors' more recent experience has, however, convinced us that at least part of the supposed benefit of using the ICBEN standardised scales of noise annoyance has been largely illusory.

A good example of this is the continuing differences between the findings obtained in community noise research carried out using the ICBEN standardised scales, and any resulting technical debates regarding the most appropriate relationships to be used in predictive modelling and assessment. See for example the different levels of community annoyance demonstrated in surveys of populations near airports around the world reported by Guski et al and summarized in Figure 1[4].

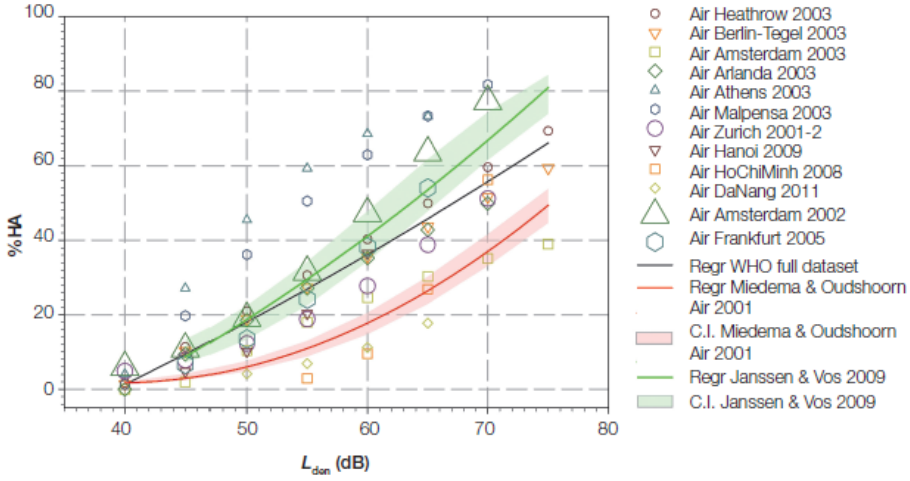

Figure 1 - calculated %HA.Scatterplot and quadratic regression of the relation between *L* and the calculated % HA for 12 aircraft noise studies, together with ERFs by Miedema and Oudshoorn[5], (red), and Janssen and Vos[6], (green). Notes: (1) The size of the data points corresponds to the number of participants.

Possible (or hypothetical) explanations for these differences include the following;

- Respondents to different noise surveys conducted at different times and different places exhibit fundamentally different responses to community and environmental noise.
- Differences in acoustic factors present when conducting research in different places and at different times contribute to observed differences in findings.
- Response measurement instruments deployed in different noise surveys, even though standardised (e.g. ISO standard questionnaire items) are not actually measuring the same things in different surveys.

The 'true explanation' if there is any such thing, is likely to be a combination of all three hypotheses set out above. Not all readers will necessarily be aware of these 'difficulties' and consequently, each hypothesis may require an element of further explanation as set out below.

2. UNDERSTANDING VARIATION IN ANNOYANCE RESPONSES

2.1 Individual differences in response

Apart from the fact that normal healthy people (not suffering from any disease or significant sensory impairment) are (generally) rather more similar than they are different physiologically, and are therefore likely to possess similar auditory capabilities, there are no particular reasons why they should all have the same attitudes and opinions when faced with different situations. In fact, it is well known that different people have different preferences, both aesthetically and socially, and are likely to be more or less satisfied with different situations. These differences become increasingly important

when considering the possible adverse health effects of chronic stress associated with negative attitudes to community and environmental noise.

Potential explanations for these differences are offered in many studies of noise annoyance based on, or at least echoing the transactional model of stress and coping, developed by Lazarus[7]. Such studies have identified certain precursors as well as implications and consequences, of noise annoyance models, all of which are integrated into a coherent model, which reflects both theoretical explanations and empirical findings of the Lazarus model.

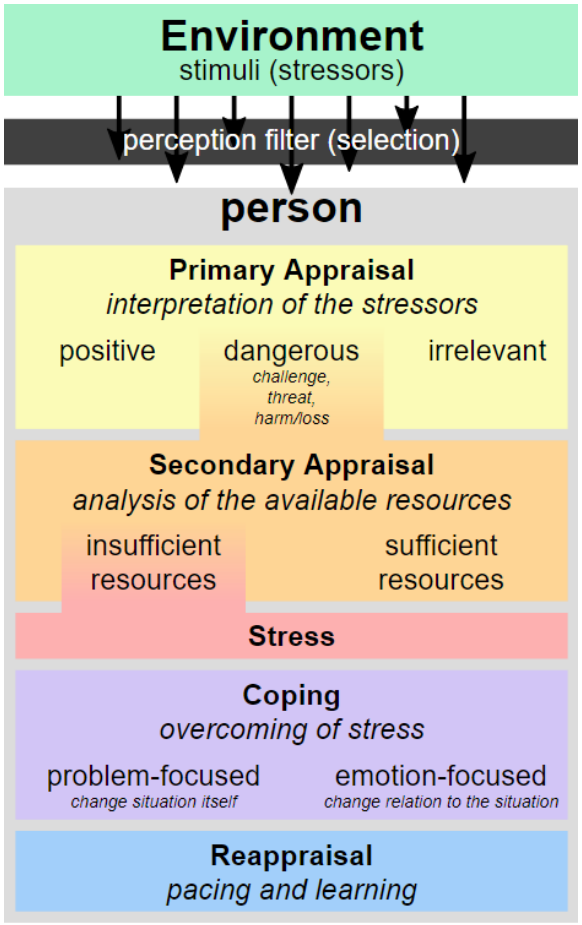

Figure 2 - Transactional model of stress and coping according to Lazarus and Folkman[7,8]

In the transactional model *stress* is explained as 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. Lazarus describes stressors as, "demands made by the internal or external environment that upset balance, thus affecting physical and psychological well-being and action to restore balance"[7].

When a person is exposed to a stressor, initially - consciously or unconsciously - an interpretation of the stressor takes place (*primary appraisal*). The model suggests that if this is judged as positive or irrelevant, no stress will occur. However, if the stressor is classified as dangerous, it is potentially stress inducing. It can then be:

- a challenge, if the situation seems manageable,
- a threat, if there is potential future harm or
- harm/loss, when harm has already occurred

In all of these potentially stress-inducing situations, according to the model, there will be another - again conscious or unconscious - assessment of whether the situation can be overcome with available resources (*secondary appraisal*), that is, an assessment about the person's *control* over the stressor.

These evaluation processes do not necessarily have to happen consecutively; they can also take place simultaneously and interact with each other. The resources can be within the person (e.g. physical or mental) as well as externally available options (e.g. social or material).

If the available resources are rated as insufficient for the given stressor, a stress response is triggered. Stress, in turn, provokes coping processes to reduce stress. Depending on the person's feelings about controllability, these mechanisms can either address the problem or the emotions:

- In the case of perceived control there will be problem-focused coping, aimed at reducing/changing the problem or the stressor itself, including strategies like generating alternative solutions or learning new skills to deal with the stressor.
- In the case of little or no perceived control there will be emotion-focused coping, aimed at reducing negative emotions, including strategies like avoiding, acceptance, selective attention, venting anger, and substance abuse.

After the coping attempts, a reappraisal of the stressor and the resources takes place. For example, after a reappraisal, a former threat might be rated as a non-stress-inducing challenge. After the reappraisal, if necessary, further efforts to cope take place.

Therefore, according to this model, decisive for the development of stress are the cognitive assessment processes and, in particular, the assessment of available resources. Stress, then, is the result of a complex interactive process between a person and the environment, with a perceived imbalance between the perceived threatening or dangerous requirement of the environment and the perceived resources. The experience of 'stress' may vary considerably between different individuals in different situations.

As stated above, many models of noise annoyance are based on Lazarus' transactional model of stress and coping. As one of the first, Stallen specified a corresponding specific noise annoyance model. Many of the models proposed later are essentially extensions or slight modifications to Stallen's model[9].

As an example, Figure 3 shows the central part of the model by Schreckenberg et al[10] (the complete model also contains sleep, health, and environmental quality of life-factors), which is the most recent model modification.

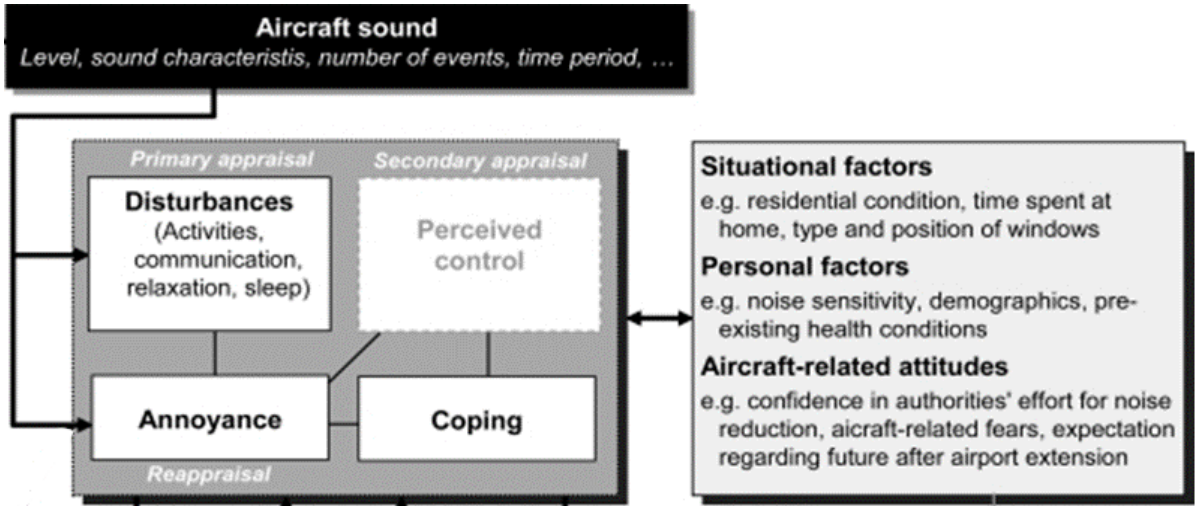

Figure 3 - Model of noise annoyance according to Schreckenberg et al[10]

In this model - just as in the other models of noise annoyance - the environmental *stressor* a person has to deal with is, of course, sound. The stress *response* is somewhat loosely described as *annoyance*. It results, analogous to the model of Lazarus, from an interaction of the appraisal of the threat of the stressor (*primary appraisal*) and the appraisal of the resources to face or cope with the threat (*secondary appraisal*).

Stallen points out that in the context of noise annoyance primary appraisal can be understood as *perceived disturbance* and secondary appraisal as the extent of the *perceived control* of the sound or noise situation[9].

Perceived control plays a central role in the emergence of noise annoyance. It may have mental, that is cognitive and affective, components (e.g. the predictability of future sound exposure), as well as behavioural components (e.g. the ability to alter exposure).

The meaning and significance of perceived control applies equally to all models of noise annoyance found in the literature, and has moreover also been underpinned by many empirical findings. Most importantly Stallen emphasises that the various components of perceived control can never be completely subjective: "To a large extent *perceived control* is rooted in how noise is managed in practice by the source". Thus, he identifies **the management of sound levels (in addition to the *actual* sound level) as important determinants of noise annoyance**[9].

Coping has a dual meaning and function in the noise annoyance models based on Lazarus. On the one hand, it is to be understood as a ***strategy*** to deal with experienced stress. In this sense, coping can - analogous to Lazarus' original model - be both problem-focused (e.g. acquiring sound insulation measures to minimize the impact of the stressor on the person) and emotion-focused (e.g. mindfulness exercises to reduce perceived stress). On the other hand, the ***state*** of the successfully achieved overcoming of stress is called *coping*, too.

Coping is seen as a process of reappraisal of the person-environment situation, that is, in Stallen's words "a matter of mental (cognitive and/or emotional) change including the formation of new behavioural intentions and (…) the undertaking of correspondent actions"[9]. At this point, "non-noise related characteristics of the person or environment" become particularly relevant. These are discussed in Section 2.3 below.

Stallen's work and later work by others help explain why individual annoyance responses to so-called 'overall' noise and 'specific' noise often bear no obvious relationship whatsoever. It is not unknown for individuals to describe or report their home environments as being generally 'quiet' and pleasant places to live, even if, when answering a different questionnaire item, they might report aircraft noise as 'very annoying', or less frequently, vice versa. In qualitative, open ended, research, respondents will often report aircraft noise as 'very annoying' while at the same time claiming that they have 'got used to the noise' and hardly notice it for most of the time. Which is the most relevant response for predicting annoyance stress related health effects? In such cases, when the respondent reports that the aircraft noise is 'very annoying' do they mean that the aircraft noise itself has some property of being very annoying (but that it hasn't actually had that effect on them as individuals), or do they mean that they themselves are very annoyed. These are two entirely different concepts and cannot be distinguished simply from the data obtained by using standardised questionnaire formats. There have been situations where people have reported noise as being annoying even at times of day when they are not personally present and thereby exposed to the noise. We can speculate as to why this happens, but the only way to find out is to actually ask people, and even then they might not have thought about it and don't actually know themselves.

2.2 Acoustic factors

Most situations vary across a wide range of different physical or objective acoustic factors present, and by no means have all, or even many of, of these factors been properly reflected by whatever acoustic metrics have been deployed in research. For example, the current and largely administrative consensus for the increasingly widespread adoption of LAeq and Lden type acoustic metrics, while beneficial for standardisation and comparison purposes, should not be accepted as a basis for assuming that these metrics represent anything other than long-time average acoustic intensity, with standardised weightings and adjustments, at any specific measurement location under the specific conditions pertaining at the time of measurement. Actual noise exposure can vary in terms of different time of day distributions, and also in terms of the representativeness of any particular day for any other day, or average day.

Repeating such measurements at different times and at slightly different locations will usually obtain at least slightly and often significantly different results. Averaging over larger measurement samples reduces variance and may be understood as increasing the stability of the measurement, but in reality it simply conceals uncertainty. If people were completely static, like trees, it might be possible to devise long time measurement programmes that obtain data representative of actual exposure, but in practice, standardised outdoor measurements (and associated noise models) are not particularly representative of individual noise exposure at all. People spend different amounts of time indoors and outdoors, and often spend a considerable proportion of the day somewhere else entirely.

Measuring personal noise 'dose' using dosimeters can provide much more representative data for each particular individual's exposure, but practical experience shows that dosimeter data is poorly, if at all, related to standard measurements of outdoor community and environmental noise.

In addition, and in many situations, adopting different weightings and 'adjustments' from those arbitrarily defined in standard acoustic metrics will often result in different outcomes. It should be noted that the available evidence to support the use of for example; the A-frequency weighting; so-called energy averaging; and even the various time of day weightings specific to Ldn and Lden, is in fact limited and even controversial in some applications.

Possibly an even bigger problem would be caused by any attempt to adjust physical (or objective) measurements for so-called non-acoustic factors arising from differences not amenable to short-term physical measurement, such as general attitudes towards the noise source and/or whichever organisation or institution is responsible for the noise and/or it's regulation and management. An interesting variation of this problem arose several years ago, when in a large scale government sponsored survey of reported attitudes to aircraft noise in the UK, average reported annoyance was higher than expected on the basis of previous research, and it was suggested by peer reviewers that this could have been a consequence of dissatisfaction with the regulator or the regulatory procedures rather than actual chronic annoyance, and that possibly perversely, this was not evidence that the results of the previous research had been in any way called into question (see [11] for full list of ANASE documents).

2.3 Individual and community response

Acoustic metrics, no matter how many associated physical or acoustic factors are taken into account, are not measurements of individual or community response no matter how strong any statistical relationship exists between them. Disregarding human chronic and acute health effects (which is effectively another topic entirely) human response can only be measured, or possibly observed, directly from observations of human behaviour or by means of subjective questionnaires.

Preliminary investigations of human behaviour have not shown much sensitivity to community and environmental noise levels, and have largely fallen out of use. Most research and assessment has therefore been forced to fall back on subjective questionnaires, leading to the ISO standard scales of annoyance reported earlier. The main difficulty with the ISO standard scales is that they record no information about the particular way that the respondent may have understood the concept of noise annoyance and any strategy they might have adopted to provide a response or to adopt any kind of coping behaviour. Considerably more information can be obtained from individual respondents by means of in-depth qualitative interviews, but this technique can be equivalently compromised by unknown bias and expectation on the part of the interviewer. The only solution to these problems is to progress slowly using both quantitative and qualitative methods, and if possible, provide meaningful yet still hypothetical alternatives for respondents to express preferences between. Perhaps it should also be more widely accepted that it is perhaps unreasonable to expect different respondents in different situations to be consistent in their attitudes to community and environmental noise as much depends on a large number of individual differences and multiple so-called non-acoustic factors, which can vary considerably between different situations.

3. CONCLUSIONS

There is no simple solution to many of these problems and any continuing search for uniformity and consistency will be more or less doomed to failure. Instead, given our understanding of the stress response and the role of non-acoustic factors in influencing the human response to noise, it would be better to focus on the particular reasons for carrying out any research or assessment and then employ whatever measurement instruments appear to be most appropriate for that particular task. In particular authorities charged with mitigating noise problems should focus on the noise management process itself, as this can be crucial in determining the annoyance response (see Stallen above), and this is often the one part of the overall situation that they can actually have any influence over. A management process that involves affected communities in key decisions, through appropriate communication and engagement procedures, is likely to result in outcomes that are more acceptable to communities; providing some control over the root cause of the environmental stressor and thus offer the potential to lower annoyance and any associated long-term health outcomes. So perhaps the goal of noise management should be to arrive at consensus outcomes rather than to seek to mitigate annoyance directly, given that the latter remains a contested concept that has provided exceptionally difficult to

quantify and relate to given sound stimuli.

ACKNOWLEDGEMENTS

Authors may acknowledge the support of the EU through H2020 research project ANIMA, which is investigating novel approaches to the mitigation of aircraft noise impacts

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