

The role of non-acoustic factors in subjective noise abatement management

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Introduction

Studies have shown that in situations of a stepwise change in noise exposure, also called high-rate changes [1], the exposure-response curve for noise annoyance against continuous sound level metrics such as L_{den} , L_{dn} , or L_{Aeq} shifts in the direction of the change in exposure. Research further indicates that this phenomenon can last for months or even years without full adaptation to the new exposure. This is the so-called change effect in noise annoyance [2].

Different explanations are discussed for the change effect [2][3]. Some of these explanations could be rejected due to a lack of evidence. Following [2], three categories of plausible explanations remain: (1) personal and contextual factors that modify the exposure-response relationship, particularly misfeasance and expectations regarding the future noise situation, change in situations of changing noise exposure [4], (2) response bias in the annoyance judgment referring to a different response criterion in steady-state versus changing exposure situations and/or at different levels of noise exposure [5], and (3) retention of coping strategies after a change in exposure [6].

As [7] points out, there is an excess in responses to be observed in high-rate change situations regarding the perceived control of the noise situation or the perceived capacity to cope with noise. The authors further state that non-acoustic factors particularly have an impact on the perceived coping capacity, which, again, is closely related to or even part of the annoyance response. It could be criticized that non-acoustic factors modifying noise responses are also present in steady-state conditions and, therefore, cannot be responsible for the observed overreaction in responses to changes in noise exposure (see [8] in response to [4]). However, a re-analysis of data from the longitudinal NORAH study on aircraft noise responses before and after the opening of a new runway at Frankfurt Airport revealed a complex dynamic relationship between noise exposure, annoyance, and attitudes such as trust in authorities [9]. According to this re-analysis, trust in authorities and noise annoyance are reciprocally related to each other with effect sizes changing in the situation of high-rate change. In this situation (here: opening of the new runway), the effect size of trust in authority on aircraft noise annoyance one year later is higher than in a low-rate change situation at the airport (quasi steady-state situation with usual variation in yearly air traffic) indicating lower trust in authorities' efforts to protect residents against aircraft noise leading to higher noise annoyance thereafter.

All in all, there is evidence that non-acoustic factors have an important role in the explanation of noise responses such as annoyance, both in low-rate as well as high-rate change situations. As a rule of thumb, up to one third of the variance

in annoyance is explained by continuous sound level metrics. Another third is explained by non-acoustic, personal, social, and situative factors. The last third of the variance in annoyance is still unexplained [10].

We argue that noise abatement management should consider the potential of personal and contextual factors in modifying the exposure-response relationship for noise annoyance. This could be beneficial for the improvement of the protection against adverse noise effects.

This paper focusses on noise annoyance as the main response to noise and on non-acoustic factors co-determining the annoyance. It starts with defining noise annoyance as a psychological stress response, explains the role of non-acoustic factors in the noise-related stress process, and concludes how noise abatement management can benefit from the consideration of non-acoustic factors in its abatement strategy.

Definition of noise annoyance

There are several definitions of noise annoyance [11]. In this contribution, we define noise annoyance as judgments of annoyance assessed by a rating scale in socio-acoustic surveys on community long-term response to noise in exposed residential areas. In detail, this is different from the acute, or short-term annoyance as assessed in laboratory studies. There is a widely used international standard for the assessment of long-term noise annoyance, the ISO/TS 15666 [12] that follows recommendations of the International Commission on Biological Effects of Noise (ICBEN) [13]. According to these recommendations the long-term noise annoyance is assessed by means of two rating scales, a verbal 5-point scale and a numerical 11-point scale from 0 to 10.

In general, noise annoyances is viewed as...

- an emotion, i.e. an elementary affective process related to the source of the noise;
- a result of disturbance of activities;
- an attitude influenced by interference of activities and personal sound information
- knowledge, i.e. annoyance judgment is greatly influenced by the “conceptual knowledge” of sounds
- a result of rational decisions involving several aspects such as the noise load, information about earlier noise loads, the sensibility of the activity that is disturbed, and costs and benefits of the results of the decision ([11] p. 514ff).

According to expert interviews on the definition of annoyance [11], noise annoyance at least consists of three elements:

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 behavioural 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).' ([14], p. 2)

The process of noise-related stress

The above-mentioned definition of noise annoyance is quite similar to the definition of environmental stress. A typical psycho-biological definition of stress is:

'Stress occurs under conditions where an environmental demand exceeds the natural regulatory capacity of an organism, in particular in situations that include unpredictability and uncontrollability' ([15], p. 1291).

According to the definition of annoyance as a noise-related stress response, the three elements of annoyance judgments refer to two aspects of the noise-related stress process: One aspect is the stressor itself, the sound, its level, duration, number of events, frequency, psychoacoustic characteristics which interferes with human behaviour and cognitive processes and disturbs these activities, which is in turn negatively evaluated. According to the Lazarus' stress model [16], this is the primary appraisal within a stress process. The other aspect is the perceived opportunities and resources to get rid of the unwanted noise stress situation, i.e. to cope with the noise. This is the secondary appraisal within the stress process. The annoyance judgment can be understood as an integration of both mentioned appraisals (reappraisal). That is, if people perceive a way to cope with noise, they will be less annoyed than those that perceive less control to cope with the noise, i.e. perceive a lack in coping capacity.

Note that as a stress response to noise, annoyance is not only an evaluative judgment of like or dislike of a (noisy) situation. There is evidence that transportation noise annoyance at least partly mediates the impact of noise on further health outcomes, particularly mental health outcomes [17].

In principle, when noise stresses exposed individuals, three ways of coping with the noise can be identified [18]:

1. Short-term coping when exposed to noise events. Here, the focus is on immediate actions and cognitions reducing the noise exposure or adaptation to the noise, e.g. by speaking louder, escaping from the noise situation, closing windows, encapsulating the noise source or by cognitive rationalization.
2. Long-term coping that refers to taking actions against the adverse effects of noise on a broader level like complaining, participating in citizens' groups, engaging in local policy and developing collective strategies to change regulations, or by moving to another domicile.
3. No coping behaviour for one or more of the following reasons: (a) The sound an individual is exposed to is not

regarded as annoying or disturbing, i.e. individuals do not perceive any discomfort in the situation when the sound is present; (b) exposed residents are able to delegate the responsibility for reducing the adverse effects of the noise to other persons or authorities or perceives others endeavour to minimise the adverse effects; (c) individuals exposed to noise for a longer period of time do not perceive any possibility to improve the noise situation, i.e. they perceive a loss of control up to learned helplessness and surrender [19].

Thus, the perception of to what extent one can cope with noise depends on the (noise) stress intensity, as well as the perceived coping opportunities and resources of the exposed individual. This includes the perception and use of opportunities of periodic restoration to renew depleted coping capacities and functional resources [20].

This is where personal and contextual factors come into play.

The role of non-acoustic factors

An initiative working currently on the development of an ISO/TS Standard for non-acoustic factors provides the following tentative definition:

'All factors other than the objective, measured or modelled acoustic parameters which influence the process of perceiving, experiencing and/or understanding an acoustic environment in context, without being part of the causal chain of this process' ([21], p. 4).

This definition refers to factors other than acoustic parameters. However, often those factors are called non-acoustic that do not refer to the source-specific sound of interest but that imply contextual acoustic aspects modifying a source-specific noise exposure-response relationship with continuous sound level metrics as exposure indicator (e.g. L_{dn} , L_{den} , L_{Aeq}). These are, for example, the background noise, the availability of a quiet façade, green space, or the window position [18]. Therefore, what is often called 'non-acoustic factor' is much more a 'non- L_{dn} ' factor as, e.g., [22] put it.

The non-acoustic or 'non- L_{dn} ' factors can be grouped in [18]

- personal factors such as fears, expectations, the individual disposition of noise sensitivity or other personal traits, and socio-demographic factors;
- social factors like socially mediated attitudes towards the source or towards authorities;
- situational acoustic-related and non-acoustic context factors, for example, the access to green spaces, the appearance of the neighbourhood, the visibility of the noise source, the predictability of the noise events.
- A fourth kind of non-acoustic factor mentioned in [18] is in particularly related to social issues of the process of noise management. Under this category of non-acoustic factors fall, e.g., trust in authorities, perceived fairness of noise management procedures, or the satisfaction with sound insulation arising from the awareness that someone is caring for exposed residents.

As argued in the stress-related model on noise annoyance by [23], non-acoustic factors are part of the noise stress process that in particular become relevant at the stage of the appraisal of the perceived control over the noise situation and of ways to cope with the noise.

Empirical evidence for this assumption comes from a re-analysis of longitudinal data of the NORAH study (Noise-Related Annoyance, Cognition and Health) [24]. In this re-analysis, the definition of noise annoyance as a stress-related multidimensional construct [14] was used to develop a hierarchical structured multiple-item-annoyance scale (MIAS) including the three aspects noise disturbance, emotional response (operationalised by the ICBEN 5-point annoyance scale), and lack of coping capacity. It turned out that non-acoustic personal and social (attitudinal) factors correlated with all aspects of MIAS but that the correlation coefficients were highest with the annoyance facet 'lack of coping capacity'. In line with this, it was found in an additional re-analysis that the above-mentioned change-effect (excess in response to changes in noise exposure) in response to the Frankfurt Airport expansion in 2011 was larger for the 'lack of coping capacity' than for the facet 'disturbances' [7].

Different types of noise interventions

Following [26], there are five types of interventions, three of them referring primarily to the noise source of interest and its pathway to the receiver, and two further types to the environmental context and to the receiver her-/himself.

Type A interventions refer to noise control at the source (e.g. silent cars or asphalt, change in traffic flow/composition, speed limit).

Type B/C interventions refer to the infrastructure and are implemented on the pathway to the recipient (e.g. noise barriers, rerouting roads, traffic tunnels, dwelling insulation).

Type D interventions follow a broader perspective of urban/transportation planning and refer to an integrative, environmental design taken the (perceived) environmental acoustic and visual context into account (e.g. high-quality outdoor environment, green and blue spaces, quiet sides).

Type E interventions are related to the noise exposed receiver and addresses his/her perceived control and coping capacities by means of education, information and – at best – engagement (stakeholder involvement). Non-acoustic factors, in particular those that are modifiable by external management, are considered to be specifically relevant for Type E interventions [25].

Towards a comprehensive noise abatement management

According to the noise annoyance model proposed by [23], the sound of a noise source affects the noise annoyance via disturbance of activities, whereas the process of noise management influences exposed individuals' perceived control over the noise situation and their perceived capacity to cope with it (see Figure 1).

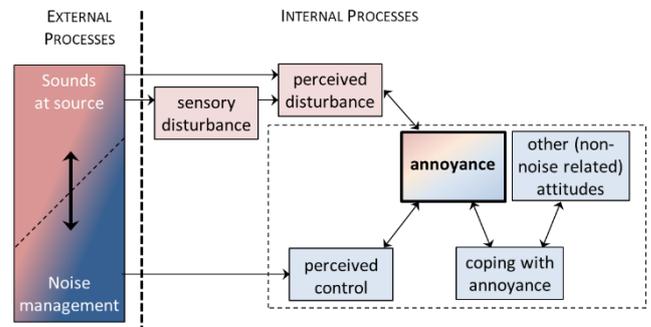


Figure 1: Stress-related noise annoyance model. Source: [23]

Regarding noise abatement, considering non-acoustic factors in a comprehensive noise management (e.g. in local noise action planning) is regarded as a promising way for preventing adverse noise outcomes. Within such a comprehensive noise management, type E interventions should not be regarded as separate from the other types of interventions. Instead, communication with and engagement of all stakeholders including receivers should be an essential part of all other types of interventions type A to D.

Conclusions

Starting with the definition of noise annoyance as a process of noise-related stress including perceived disturbances, emotional responses and a perceived lack of the capacity to cope with noise it is argued that non-acoustic co-determinants of annoyance are an essential part of the noise stress process, and they particular address exposed individuals' perceived control over the noise situation. Especially attitudinal factors such as trust in authorities, perceived procedural fairness and attitudes towards the source can be addressed by involving stakeholders in the process of planning and implementation of noise interventions. The communication with and engagement of individuals exposed to noise is regarded as crucial for a successful noise abatement and should be an essential part of a comprehensive noise abatement management.

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