First Steps in the Development of the new WHO Evidence Review on Noise Annoyance

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Summary
WHO published Guidelines for Community Noise in 1999, and Night Noise Guidelines for Europe in 2009, and was asked to provide recent scientific evidence and recommendations for policy-makers of the Member States of the European Region. Following a strict protocol, WHO asked external experts to provide reviews for 8 topics: Cardiovascular diseases, Sleep disturbance, Hearing Impairment and tinnitus, Annoyance, Mental health effects and well-being, Birth outcomes, Combined exposures, and Intervention effects. This paper describes the outline and protocol of the procedures used for the evidence review in general, as well as the special results of the literature search and systematic review on noise annoyance with respect to aircraft, road traffic, railway, wind turbine, and combined source noise. The exposure-response relations shall generally be examined for steady-state noise situations, but it will be pointed out that there are some conceptual problems associated with the distinction between steady-state and changed situations in the case of aircraft noise. At the time of writing this manuscript, the work is still going on, but more results will be presented at the conference.

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1. Introduction

The current WHO Guidelines for Community Noise [1] are based on the review of Berglund & Lindvall [2]. This outstanding work handles almost all of the topics which are still important today – from physical aspects of environmental noise to the broad range of effects on humans, especially on health risks. The old guideline paper handles different noise sources, and mentions among others that there is increasing evidence of differences between noise sources at comparable LAeq levels with respect to noise annoyance It also mentions the famous paper by Miedema & Vos [3] which provides a comparison of several annoyance studies and clearly shows considerable differences between noise sources at comparable LAeq levels with respect to noise annoyance. This paper was probably too early to change the WHO guideline policy, not to distinguish between different noise source types with respect to guideline values. For instance, it is said that serious annoyance generally is associated with LAeq,16h levels of 55 dB and above – independent of the noise source.

Ten years after the edition of the Guidelines, WHO [4] published the Night Noise Guidelines (NNG), a paper that can be seen as an extension to the old guidelines, but it differs from them at least in one remarkable aspect: While the old guidelines do not explicitly mention criteria for scientific evidence, the new ones distinguish between "sufficient" and "limited" evidence for an effect of noise on sleep. They use the term "sufficient evidence" whenever a causal relation has been established between exposure to night noise and a health effect, bias has been excluded, and the biological plausibility of the relation between noise and health effect is also well established. In contrast, the term "limited evidence" is used, when a relation between the noise and the health effect has not been observed directly, but there is available evidence of good quality supporting the causal interpretation.

Five years after the edition of the Night Noise Guidelines, WHO Europe turns the scientific evidence screw considerably more tightly: Qualitative terms, like "sufficient evidence", are not sufficient as a base for guidelines. Instead, an explicitly described literature search together with explicit inclusion/exclusion criteria, and quantitative indicators of the scientific evidence are requested. These requirements lead almost automatically to meta-analysis, where exposure-response curves and effect-size measures play the major role. WHO asked experts to provide reviews for 8 topics: Cardiovascular diseases, Sleep disturbance, Hearing Impairment and tinnitus, Annoyance, Mental health effects and well-being, Birth outcomes, Combined exposures, and Intervention effects. This paper describes the outline and protocol of the procedures used for the evidence review in general, as well as its application to the literature search and systematic review on noise annoyance with respect to aircraft, road traffic, railway, wind turbine, and combined source noise.

2. The protocol for the WHO Environmental Noise Guidelines for the European Region

Environmental noise is defined as noise emitted from all sources except sources of occupational noise exposure in workplaces. The health outcomes for which the evidence will be systematically reviewed are the following:

a) Effects on sleep
b) Annoyance
c) Cognitive impairment, mental health and wellbeing
d) Cardiovascular diseases
e) Hearing impairment and tinnitus
f) Adverse birth outcomes
g) Effects of intervention measures

The main objectives are to assess the strength of association between exposure to environmental noise and incidence or prevalence of adverse health effects for the general population and, where possible, to quantify the risk of these health effects with an incremental increase in noise exposure.

Study types: We will include prospective and retrospective cohort studies, case-control studies and observational or experimental cross-sectional studies of persons exposed to environmental noise.

Type of participants: Studies including members of the general population as well as specific segments of the population particularly at risk, such as children or vulnerable groups, will be considered.

Type of exposure: For studies to be included, noise exposure levels should be either measured or calculated and expressed in decibel values. They should aim to be representative of the individual exposure of the study participants (for most observational studies, this would be the dwelling location or home). Calculated levels for transportation noise (road, rail, air) must be based on traffic data reflecting the use of roads, railway lines and in- and outbound flight routes at airports.

Type of confounders: The relation between exposure to noise and a health outcome can be confounded by other risk factors. WHO did not define inclusion or exclusion criteria in this case, but proposed for each study to assess which possible confounders have been taken into account.

Type of outcome measures: Studies will be included if they address the following primary outcomes. We will include a particular annoyance study only if the outcome has been assessed as proportion of self-reported annoyed or highly annoyed people or average self-reported annoyance assessed on a continuous (if possible, standardized) scale.

Search for already available systematic reviews: As a first step, WHO performed in 2014 a literature search for all available systematic reviews and meta-analyses on environmental noise. The databases searched include Medline/Pubmed; Scopus (includes Embase); PsycInfo, Web of Science Database and ScienceDirect. The search included systematic reviews and meta-analyses published after 2000. This search lead to 37 annoyance reviews, which were evaluated by two annoyance experts, using the AMSTAR protocol [5]. The experts concluded that none of the reviews fulfilled all expectations, they should at least be updated.

Search for individual annoyance studies: A new literature search was started, using the data bases mentioned above plus BASE (Bielefeld Academic Search Engine), DIMDI (German Medical Information System), EBSCO, Ingenta-Connect, RIVM, DEFRA, ICBEN, SASDA (Japanese Socio Acoustic Survey Archive), Google Scholar, and Springer-Link. As far as possible, we used the search string "((noise AND annoyance) AND ((exposure-response) OR (dose-response))", and restricted the search to the publication years 2000 – 2014. At the end, we got more than 1.700 hits, of which 87 were non-redundant and described observational studies on residents exposed to noise from at least one of the noise four sources: road traffic, rail traffic, airports, industrial sites, and wind turbines.

Preliminary Inclusion/Exclusion criteria: We decided to include only papers which fulfil the above mentioned criteria concerning study type, participants, type of exposure, and type of outcome measure. With respect to confounders, we decided to handle papers containing a potential second risk factor besides noise (e.g., vibration) separately. As a first step, we judged the global quality of the paper from the title, abstract and methods section of the paper, using parts of the GRADE system [6] as a basis, especially with respect to the study limitations (e.g., method of participant selection, method of noise calculation, method of annoyance measurement). As a result, we got a list of 46 annoyance papers that could possibly be used in the evidence review.

First data extraction: With help from a third expert, we produced an extensive description of each of the 46 papers, containing data about study details like type of study, main type of noise source, survey date, location, rationale for site selection, noise metrics used, distribution of levels in the survey, number of respondents, response rate, non-response analysis, annoyance scale used, main outcome measure, definition of highly annoyed, additional non-acoustic variables, statistical approach, type of exposure-response relationship, and a formal rating of the study quality according to Merlin et al. [7].

Second stage of Inclusion/Exclusion criteria: The list of 46 papers was used for a deeper evaluation of the quality of studies. We mainly used 4 quality criteria: the selection of study participants, the quality of the acoustic calculation procedures, the quality and comparability of the annoyance scale used, and the quality of the effect calculations. We included 34 papers, containing a total of 43 individual studies. We excluded papers with suboptimal quality (e.g. unclear rationale for the selection of study participants, unclear or incomparable method of acoustic calculation, incomparable annoyance scale), and all papers on interventions, because these are handled by another group. But we will come back to the topics of “steady-state” and “change” with respect to aircraft noise later in this paper.

Just a word about “incomparable annoyance scale”: We decided to use the ICBEN/ISO-type of annoyance measurement [8, 9] as a standard. This standard relates both to the annoyance question (asking for a certain location, and integrating over a certain time) and the type of response scale (5-point verbal with equal steps, or 11-point numerical). Papers that differed slightly from this standard were also included, provided that the annoyance questions and response scales were at least similar with the ICBEN standard. An exception is the 5-point verbal scale containing “no notice” as a first step, followed by 4 annoyance steps. This type of scale is sometimes used with sounds from wind turbines. Although the first step contains no explicit annoyance rating, the authors often assume this answer to be the comparable with the second response step “notice, but not annoyed”. While this type of scale is not strictly comparable with the ICBEN format, it can be argued that the combination of steps 1 and 2 together with the other 3 steps make a 4-point annoyance scale which can partially be compared to other verbal scales [10].

Selection of effect-size measures: Since WHO asks for quantitative expressions of the evidence, quantitative effect-size data are required. We considered 5 types of effect-size measures:

- Pearson correlations for LAeq vs. Annoyance-Scale, 5-p verbal (raw scores), and 11-p numeric scale (both raw scores), each for LAeq,16h. LAeq,24h, and Lden)
- Percent HA for grouped original data at 50 and 60 dB LAeq for road, rail, and aircraft noise, % HA at 35 and 45 dB for low level noise source types; together with number of participants at each level. This type of measures allows to calculate the effect difference for a 10-dB-increase of the noise level
- Equation / parameter values (e.g. B or exp(B) for logistic regression) for the model, specified for type of exposure-response relationship (e.g. linear regression; logistic regression: binary / ordinal; multilevel group regression; polynomial fit; …)
- Bivariate non-linear regression LAeq vs. %HA (R^2)

- Multivariate non-linear regression (adj. for moderators/confounders) LAeq vs. %HA (R^2), specify moderators.

This selection of effect-size measures was sent to the authors of the 43 studies which were preselected. At the time of writing this manuscript, the process was ongoing.

Final data extraction and management: The two reviewers will independently extract data from the articles and respective author-answers that are on the list of included individual studies. The data extracted in the first stage will be supplemented by the respective effect-size measures provided by the authors. A common decision will be made with respect to the final effect-size measure for each group of papers which relates to the same noise source type. Additional data required for the formal meta-analysis will be added (e.g., an estimation of the publication bias), and the calculations will be done. At the end, a formal meta-analysis will be written, together with a text explaining the main outcomes. In cases were a formal meta-analysis cannot be performed (e.g., because there are very few studies), a narrative review will be written. The text will close with an assessment of the overall quality of evidence for each group of studies.

3. A note on the distinction between "steady state" and "change situations"

It has often been observed that annoyance responses in "change situations" (e.g., when sudden increase or decrease of noise levels occur, when a new infrastructure went into operation, flight routes have been changed) differ from responses in steady-state situations [11-13]. Brown & van Kamp [13] use the term "excess response" to denote the increase of attitudinal or annoyance response associated with increased road, rail, or aircraft traffic, even if the noise levels in terms of LAeq did not increase. The authors propose the term "under response" to denote the decrease in attitudinal or annoyance response associated with decreased transportation noise. In both cases, the height of the annoyance response differs from that observed under steady-state conditions: with increasing traffic, annoyance increases more than could be expected by the noise levels observed; with decreasing traffic, annoyance decreases more than could be expected by noise levels.

A major problem in this field is the definition of "change situation", and its difference to "steady state situations": Transportation noise rarely is stable over time; e.g. road and aircraft noise often increase during daytime and decrease during nighttime, both are more intense during the warm seasons, as compared to the cold seasons. In other words, even if there is no general trend towards an increase or decrease of noise levels and/or the number of loud events, there are day-to-day and seasonal fluctuations. We still tend to call these situations "steady state", as long as there is no statistical long-term trend or abrupt change with respect to levels or loud events. But how to define "long-term trend" and "abrupt change"? In the case of aircraft noise, Horonjeff & Robert [11] proposed to consider the difference in the long term averages of the exposure variable compared with the normal day to day variability as a measure of the degree of change. That is, they propose to use the number of standard deviations of the day-to-day average exposure before and after a change in order to define the degree of change. Horonjeff and Robert [11] also point to the influence of time: the rate of exposure change over time may be rather low (which is true for most civil airports) or high (in case of abrupt changes), and the duration of the change may be temporary or permanent.

The next question relates to the type of exposure variable used for estimating the rate of change. This has severe consequences for the direction of change: Given the typical development of civil airports, we observe two opposing trends from year to year: the long-term LAeq levels decrease, but the number of flights (loud events) increase. If we only consider LAeq noise levels as estimates of exposure in this situation, we get a low-rate negative trend, and if we only consider the number of loud events, we get a low-rate positive trend. Unfortunately most scientific studies only report LAeq levels, thus may risk running into the "Airport Noise Paradox" which Freytag [14] described as "Ldn drops while problem grows": In spite of the decrease of long-term LAeq levels at civil airports, residents' complaints and annoyance judgments rarely follow the long-term LAeq decrease – resulting seemingly in an increase of annoyance at comparable LAeq levels over the years, even in so-called steady-state or low-rate change situations.

Another problem in defining "change situations" relates to the observation that an "excess effect" may occur a considerable time **before** the implementation of a new infrastructure [15, 16]. Job et al. [15] interviewed residents in the vicinity of Sydney International Airport about their satisfaction/dissatisfaction with aircraft noise about one year before and some months after a considerable change in flight routes: " The present evidence that reaction to the noise changes with knowledge of future changes in exposure, even before any change in noise exposure occurs is striking." (p. 2424). If this observation can be generalized to other airports expecting an abrupt change in flight operations, we should change our concept of "change situations". Instead of using only acoustic variables as indicators of change, we should also try to incorporate social factors (like public discussions and expectations). We should also ask whether annoyance judgments in "before" situations can really be used as a baseline indicating a steady-state situation.

We don't have a solution for this bundle of problems, and with respect to the WHO evidence review on annoyance, we will try to distinguish between "steady-state", "low-rate change" and "high-rate change" conditions, leaving the latter mainly to the WHO Intervention group.

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