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# On comparing exposure-response functions for annoyance – more tolerance?

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## ABSTRACT

Publication of the systematic review for annoyance as part of the WHO Environmental Noise Guidelines has resulted in a considerable increase in activity in comparing and contrasting exposure-response functions for annoyance developed by different authors on different data. It is not the purpose of this paper to re-hash the arguments of these comparisons. Instead, its intent is to highlight some quite fundamental, though apparently not universally acknowledged, issues concerning statistical intervals used in these comparisons. Depending on whether the functions being compared are from individual exposure-response studies, or are syntheses of multiple exposure-response functions, different statistical intervals are appropriate. One interval that does have widespread use is the Confidence Interval, but this is not appropriate to assess how an exposure-response function from an additional study conforms to a function previously synthesized from multiple studies. The Tolerance Interval is required for this purpose. It is fortunate that both Confidence and Tolerance Intervals are available for what is known as the Miedema functions. Examples are provided in this paper of some inappropriate comparisons – and how use of the Tolerance Interval provides some additional insight into the latest WHO annoyance synthesis for road traffic noise annoyance.

Keywords: Road traffic noise, Annoyance, Exposure-response, Noise, Tolerance intervals, Confidence Intervals.

## INTRODUCTION

The origins of this paper lay in the experience of the current author, and colleagues, in reporting the results of the Hong Kong study of the annoyance responses of the Hong Kong population to their exposure to road traffic noise (Brown et al., 2015). That exposure-

response survey included 10,077 completed interviews of a random sample of residents, with an overall response rate of 76%. Questionnaire design and application protocol followed the international standard for measurement of annoyance (ISO, 2003) applicable at that time. Annoyance was measured on a 0–10 numeric scale ('…what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by road traffic?') with' not at all' and 'extremely' as end labels of the scale.

Having thus established a high-quality ERF for annoyance from road traffic noise in Hong Kong (Figure 1), the obvious question was: how did this ERF compare to earlier ERFs, particularly given the different population and the different urban form in HK?

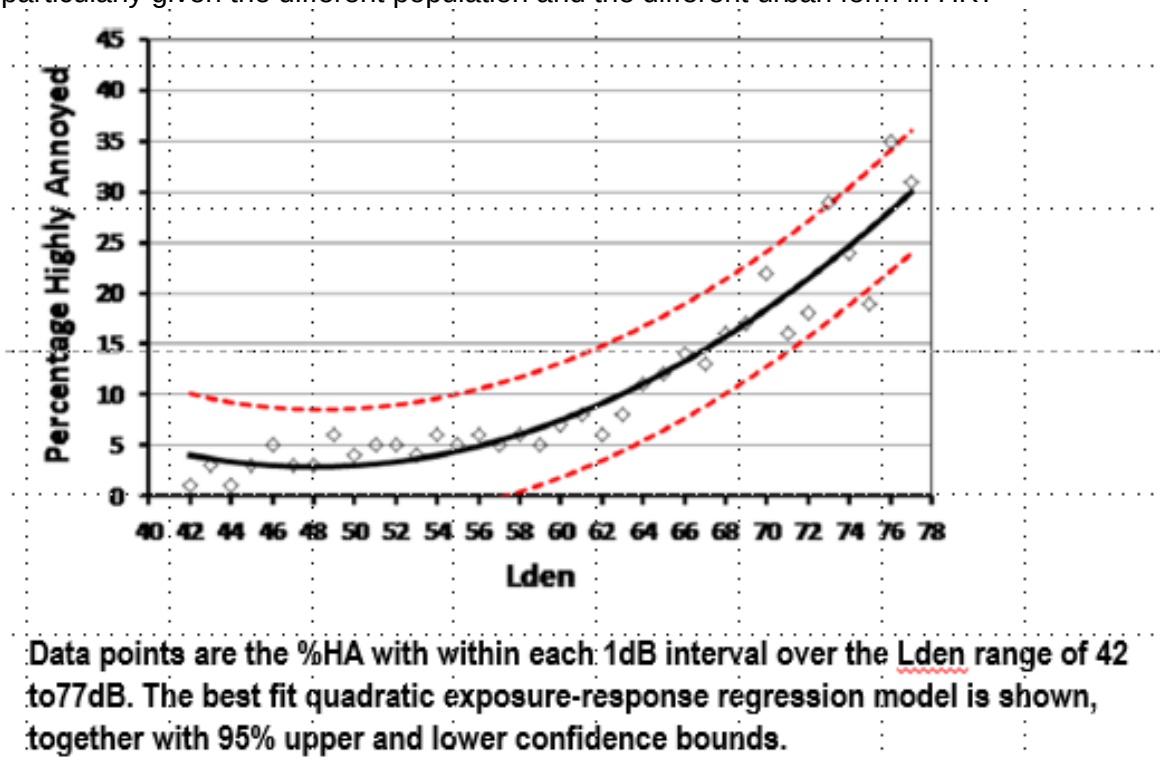



Figure 1: The ERF for annoyance with road traffic noise in Hong Kong (from Brown et al., 2015)

**ANALYSIS**

The most recent synthesis available at that time, of road traffic annoyance ERFs, was that of Miedema and Oudshoorn (2001) – a synthesis of 26 road traffic noise annoyance studies, with 95% confidence bounds estimated for the ERF. This comparison with Hong Kong is shown in Figure 2. This would to suggest that Hong Kong responses are considerably lower than those in the Miedema syntheses at the higher noise exposures, but slightly higher at the lowest exposures, lying outside even the 95% Confidence Limits of the Miedema curve.

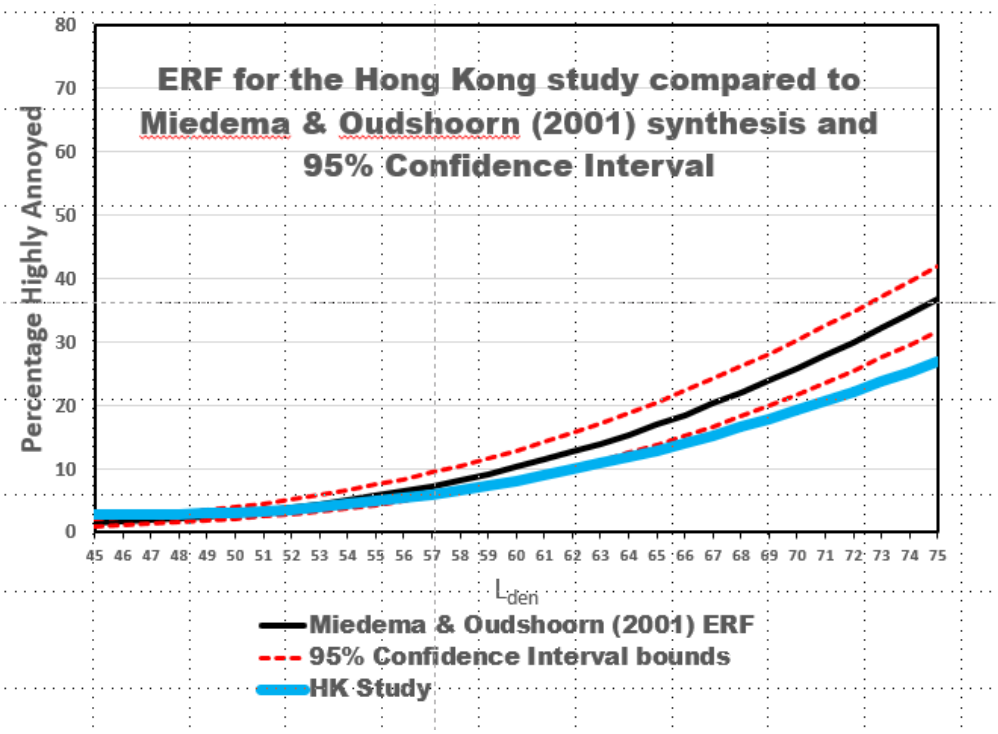



Figure 2. Comparison of the Hong Kong ERF with the Miedema and Oudshoorn (2001) synthesis, and its Confidence Intervals.

But is the comparison depicted in Figure 2 - using Confidence Intervals of the synthesized curve - appropriate? The Miedema curve is a synthesis of 26 earlier ERF studies; the Hong Kong Curve is the ERF from a survey in one city.

A paper by the same authors on construction of the exposure-response relationships for annoyance (Groothuis-Oudshoorn & Miedema, 2006) noted the availability of several different limits:

- "…A ***confidence interval*** *gives* bounds for the mean (over all studies) of the probability of exceeding a given cutoff on the annoyance scale."
- "…A ***tolerance interval*** gives bounds for the probability of exceeding a given cutoff on the annoyance scale in a randomly draw new study with an infinite number of respondents."
- "…a ***prediction interval***, gives bounds for the probability of exceeding a given cutoff on the annoyance scale for a randomly drawn respondent from a randomly drawn study." ISO 1996 (2016)

The Hong Kong study can be considered a '*randomly drawn new study with an infinite number of respondents'*. Hence it is the tolerance interval of the synthesized Miedema curve that should be utilized in comparisons – see Figure 3. The Homg Kong ERF lies within the Tolerance Limits for the synthesized Miedema curve. This finding can be summarized as: the ERF of the Kong Kong study can be considered to be drawn from the same population of ERFs as were those of the 26 studies originally synthesized in Miedema and Oudshoorn (2001).

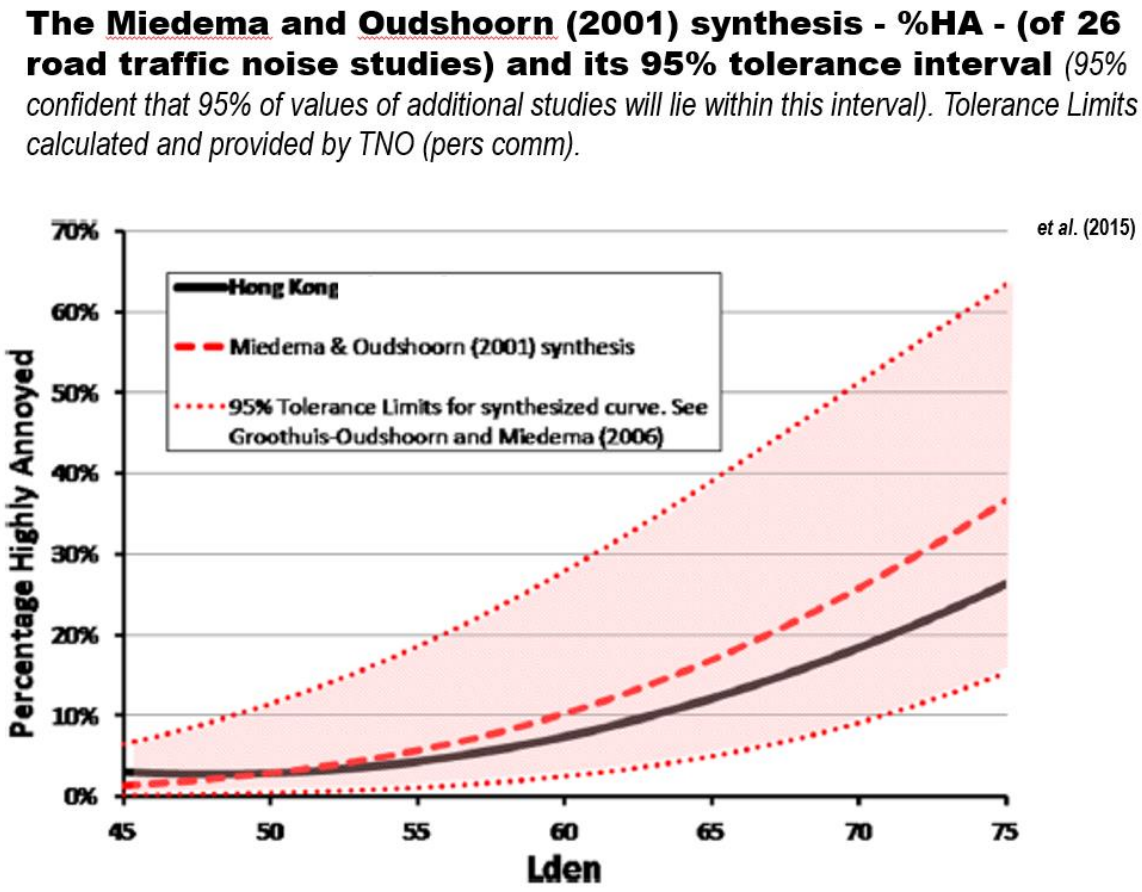



Figure 3. Comparison of the Hong Kong ERF with the Miedema and Oudshoorn (2001) synthesis, and its Tolerance Intervals (after Brown et al., 2015). The Hong Kong ERF falls within the Miedema Tolerance Limits.

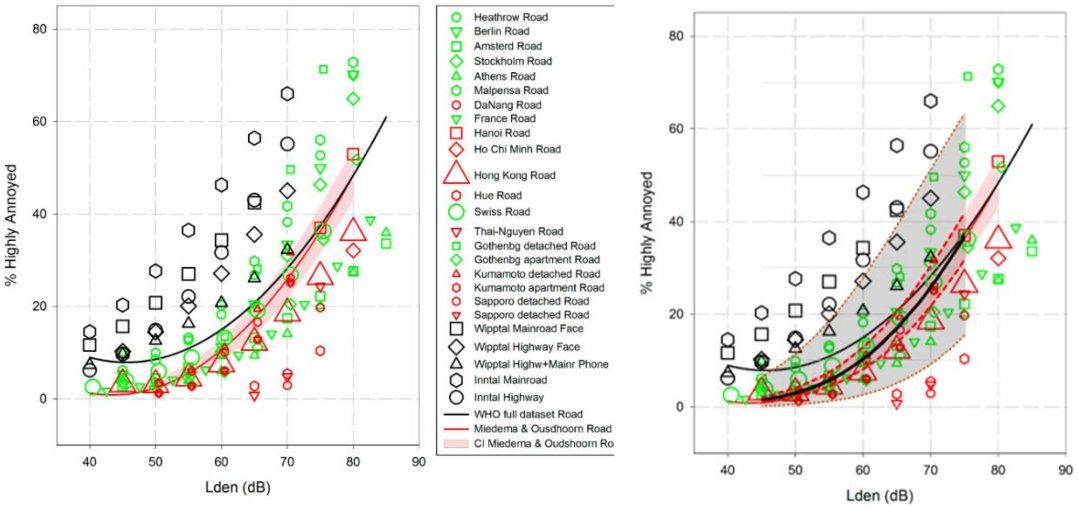
The more recent road traffic noise annoyance synthesis conducted for the WHO Environmental Noise Guidelines (Guski et al., 2017) was based on 26 studies of traffic noise annoyance responses in the period 2000-2014. The source data for these studies is shown in Figure 4. The authors estimated two ERFs, one for the 'full WHO data set' and the other 'excluding Alpine and Asian studies'.

There has been considerable, and ongoing, debate concerning the results of the WHO synthesis, and comparison with the earlier Miedema synthesis. At the critical lower 40-60dB levels, the 'excluding Alpine and Asian' ERF was closer to the Miedema and Oudshoorn (2001) ERF than was that for the full WHO data set. Schreckenberg and Hong (2021), in their ICBEN review, rehearsed the issues in the above debate on the WHO annoyance synthesis. They recognized that different input data, and different methods, will lead to different results. They also noted that the synthesis had worked within the strict study protocol for the systematic reviews provided by the WHO, including inclusion criteria for studies.

Confidence and Tolerance Intervals were not available as part of the WHO synthesis, but it is still useful to consider how knowledge of the Miedema and Oudshoorn (2001) Tolerance Limits can contribute to this debate.

The %HA at 5dB exposure intervals for each of the studies is plotted in Figure 4a. There is clearly a major study effect in the results, with the ERFs of some studies consistently being higher or lower than the overall ERF results. Notably, the valley (Alpine) studies have very high %HA across the exposure range, and three of the Asian studies have predominantly low responses (and a highly restricted range of exposures 65-75 dB within the study). The large (10,077 respondents) Hong Kong study was also classified as an Asian study, though the %HA was more closely aligned with the Miedema and Oudshoorn (2001) ERF.

The same data is shown in Figure 4 (b), but with the Miedema Tolerance Limits superimposed. This shows that most of the ERFs can be said to come, with 95% probability, from the same population of studies as that on which the Miedema and Oudshoorn (2001) ERF was based. It is only the four Alpine valley studies, and the three Asian studies with the restricted 65 to 75 dB range, that are not from this population. That the Alpine studies were associated with ERFs that were higher than various ERF syntheses for annoyance has been known for several decades (Lercher, 1998; Lercher et al., 2008).




**(a) ER 'curves' (scatterplots) of all road traffic noise studies (Guski et al., 2017) and overall quadratic regression ERF (black line), together with the Miedema and Oudshoorn (2001) ERF (red line). Black symbols refer to 'Alpine' valley studies, red symbols refer to 'Asian' studies, and green symbols refer to 'European non-valley studies'. Panel (b) shows the same as (a) but has been overlaid with the Miedema and Oudshoorn (2001) ERF tolerance limits.**

Figure 4. The Guski et al. (2017) data and analyses for road traffic noise annoyance considered in the text.

## CONCLUSIONS

There is a need for more care when undertaking comparisons of different ERFs for annoyance responses to noise. In particular, different statistical limits are appropriate depending on whether the comparator ERF is a single study relationship, or a relationship synthesized from analysis of a set of individual ERFs.

Examination of how any new ERF relates to a synthesized curve requires knowledge of the Tolerance Limits of the synthesized curve – such limits are available for the Miedema and Oudshoorn (2001) synthesis for road traffic noise

Comparison of the individual-study ERFs used in the Guski et al. (2017) synthesis for the WHO annoyance review for road traffic noise with the Miedema Tolerance Limits showed that only a handful of the 26 individual ERFs were outside the Tolerance Limits of the Miedema synthesis.

New ERFs that fall within these Tolerance Limits can be said to be drawn from the same population of ERF studies as were those used in the estimation of the synthesized curve.

This is not an observation of which ERF's may be 'right' or 'wrong', but it does suggest where there may be differences in response between studies to which analysts might usefully turn their attention.

A focus solely on synthesized ERFs overlooks the variability between the ERFs of individual studies. While such syntheses are important for policy-making and standard-setting with respect to traffic noise limits (Miedema and Oudshoorn (2001) made an explicit observation that standard setting should be based on the mean of all ERFs in their meta analysis), there has been rather too much argument over what are relatively fine differences arising in different syntheses – at least when considered in the context of the variability in the ERFs of the individual studies...a little more tolerance would be appropriate .... .

**References**


Brown, A. L., Lam, K. C., & van Kamp, I. (2015). Quantification of the exposure and effects of road traffic noise in a dense Asian city: a comparison with western cities. *Environ Health*, *14*, 22. https://doi.org/10.1186/s12940-015-0009-8

Groothuis-Oudshoorn, C. G., & Miedema, H. M. (2006). Multilevel grouped regression for analyzing self-reported health in relation to environmental factors: the model and its application. *Biom J*, *48*(1), 67-82. https://doi.org/10.1002/bimj.200410172

Guski, R., Schreckenberg, D., & Schuemer, R. (2017). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. *Int J Environ Res Public Health*, *14*(12). https://doi.org/10.3390/ijerph14121539

ISO. (2003). *ISO/TS15666:2003 Acoustics–Assessment of Noise Annoyance by Means of Social and Socio-Acoustic Surveys*. International Organization for Standardization, Geneva; Switzerland.

Lercher, P. (1998). *Deviant dose-response curves for traffic noise in "sensitive areas"?* Inter Noise 98 Christchurch. https://ince.publisher.ingentaconnect.com/content/ince/incecp/1998/00001998/00000005/art00061#

Lercher, P., de Greve, B., & Botteldooren, D. R., J. (2008). *A comparison of regional noise-annoyance-curves in alpine areas with the European standard curves* 9th International Congress on Noise as a Public Health Problem (ICBEN), Foxwoods, Connecticut. http://www.icben.org/2008/PDFs/Lercher_et_al_alpine_areas.pdf

Miedema, H. M. E., & Oudshoorn, C. G. M. (2001). Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and their Confidence Intervals. *Environmental Health Perspectives 109*(409-416).

Schreckenberg, D., & Hong, J. (2021). *Research on community response to noise 2017 to 2021.* ICBEN 2021, Stockholm.