COMPARISON OF NOISINESS FUNCTIONS FROM DIFFERENT NOISE SOURCES
METHODOLOGICAL PROBLEMS AND SUBSTANTIVE RESULTS

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Noise as a Public Health Problem

Volume 2

Editor

Giovanni Rossi, M.D.

Edizioni Tecniche a cura del
CENTRO RICERCHE E STUDI AMPLIFON
Milano, Italy
Novembre 1988

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1: .INTRODUCTION.

Environmental noise sources like road traffic, aircrafts, railway lines, factories, construction sites etc. seem to be differently 'noisy' and annoying for exposed residents. But what is the magnitude of such differences? For a quantification two perspectives are possible:

(1) How large is the difference in annoyance in case of equal noise exposure?

(2) How large is the difference in noise exposure which causes equal annoyance?

The first question reflects the social-scientific view. The second question is fundamental if 'noisiness' differences shall be applicated in noise regulations or laws, e.g., immission limits in residential areas.

Since 'stimulus' indices and 'reaction' variables correlate only moderately, results on (1) and (2) are not directly convertable. Furtheron it is more or less impossible to find areas with equal noise exposure or equal annoyance impacts with respect to all relevant parameters. Thus a statistical solution has to be found for convergent answers on both questions. Two steps are necessary:

- Defining a 'noisiness function' which reflects the relationship between acoustical stimulus (exposure, noise) and reaction (behavioral effects, annoyance) for each relevant noise source;
- Quantifying noisiness differences by comparing noisiness functions in psychological and acoustical terms.

(Terminological note: The term "noisiness function" shall denote any function which relates both noise exposure to noise effects and noise effects to noise exposure).

Some of the resulting methodological problems shall be treated here (for a more detailled discussion see ROHRMANN, 1983; cf. also FIELDS & WALKER, 1980; SCHULTZ, 1980).

2: DEFINING NOISINESS FUNCTIONS FOR NOISE SOURCES.

In a usual noise annoyance survey, individual data on behavior in response to noise (B) are gathered with respect to selected acoustical stimulus levels (A). This enables a scattergram of A and B, and the contingency can be measured by a correlation coefficient (common results range from r_{AB} = .30 to .60). If the degree of annoyance caused by a noise level shall be expressed in a general 'noisiness function', several decisions are required:

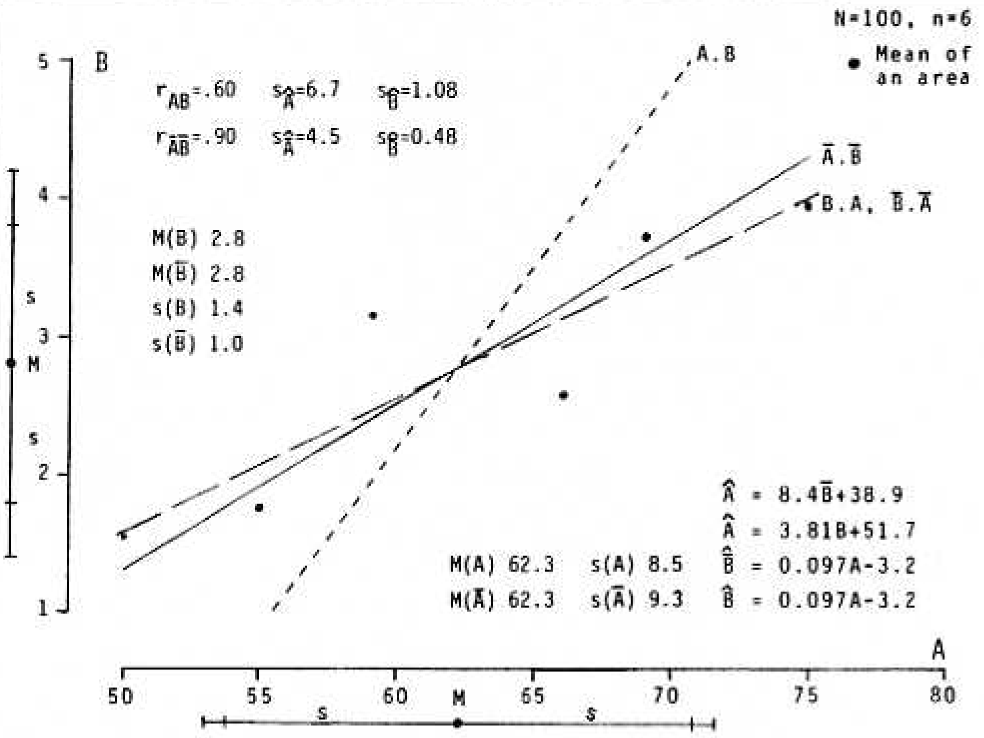
(1) Individual or mean reaction data (B, $\bar{B}$)?
A fictive data set shown in Box 1 may illustrate the problem. In this case (100 respondents in 6 areas) the correlation is 0.6 on the individual basis (r_{AB}) but 0.9 if the means of A and B per area are used ($r_{\bar{A}\bar{B}}$, n=6, grouped or collective data). For the present purpose of noisiness comparisons it seems appropriate to use mean reactions because usually no individual noise data are available, aggregated noisiness functions are more stable and the point of view here is mainly 'ecological'.

(2) Linear or non-linear A-B-function?
Theoretically a S-shaped function is to be expected for the relationship of A and B. Yet the inspection of empirical data shows that in the relevant range between L_m = 50 and 75 dB(A) a linear function is quite appropriate, at least if means on reaction scales are used (and not dichotomies like "% highly annoyed"). Additionally linear solutions have statistical advantages.

(3) Fitting of functions according to deviations in A or in B?
Usually a 'conventional' regression approach is made, namely predicting B by A (according to the cause-effect relation). But in the mentioned

Box 1

TEST DATA "X-NOISE": REGRESSIONS A ON B AND B ON A (IND./COLL.DATA)



Abbr.: A = acoustical stimulus; B = behavioral reaction; Ā, B̄ = mean values per area; N = number of respondents; n = number of areas; M = mean; r = correlation; A.B etc. = regression lines; Â etc. = estimation by regression function.

legislation context an opposite perspective is suggested. Thus two regression lines are possible, A.B and B.A, or Ā.B̄ and B̄.Ā for mean reactions, as shown in Box 1. (Note: In this special case B.A and B̄.Ā fall together because A is grouped).

There is no substantial justification for one of these solutions. It seems more appropriate to compute 'non-directed' A-B-functions (nAB), as done in ROHRMANN et al. (1980) or SCHOMER et al. (1981). Several approaches are possible; a fundamental rationale was given already by MADANSKY (1959), using error terms for both related variables. Given certain conditions, a simplified solution for B = mA + c is:

$B = (s_B/s_A)A + \bar{B} - (s_B/s_A)\bar{A}$,

yielding a straight line in between the two usual regression lines (cf. ROHRMANN, 1983). The main advantage is that corresponding values in

A or B are convertable by only one function which applies equally to the relations A-B and B-A.

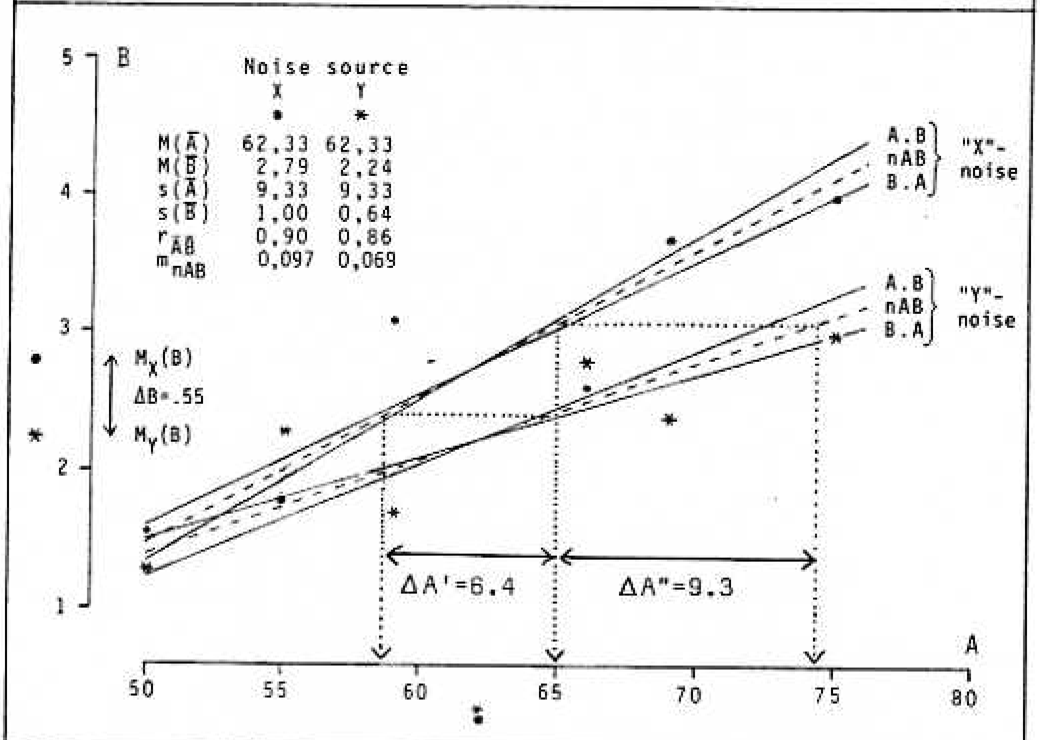
3: QUANTIFYING THE NOISINESS DIFFERENCE BETWEEN TWO SOURCES.

If the magnitude of annoyance caused by two different noise sources shall be compared and if homologous noisiness functions are defined in both cases a direct statistical comparison is possible. The difference in annoyance units B can be expressed at any acoustical level, and it can be transformed into units of the stimulus scale A. Naturally the result depends substantially on the type of noisiness function (e.g., various regression approaches like those in Box 1 or nonlinear curves).

Box 2 demonstrates the procedure, using the data of Box 1 ("X-noise") and an additional test data deck ("Y-noise"). The example refers to mean reactions and a linear non-directed A-B-function. Within such comparisons two problems arise:

Box 2

NOISINESS DIFFERENCES X-NOISE/Y-NOISE (TEST DATA "X", "Y")



Abbr.: Δ = difference; m = slope; nAB = non-directed A-B-function. Cf. also Box 1!

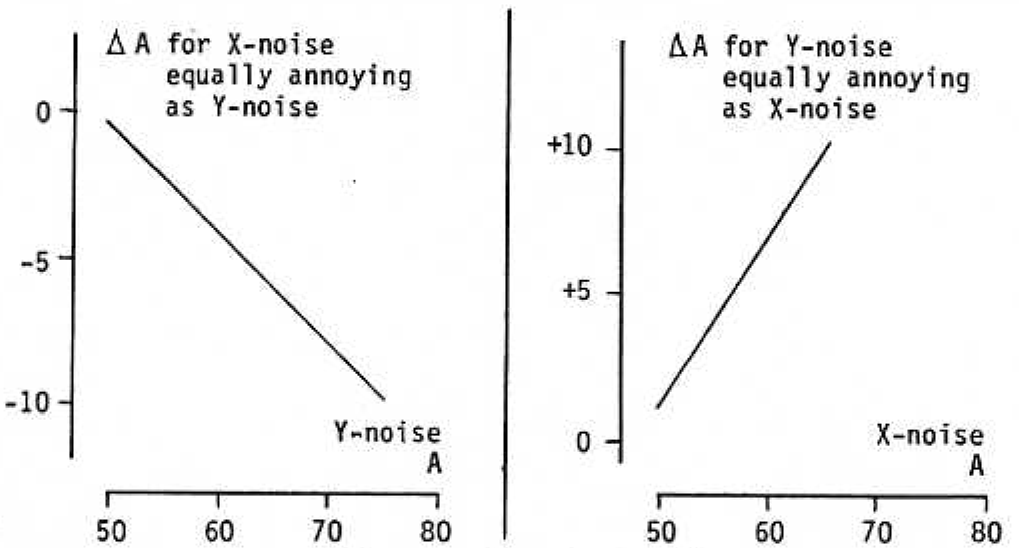
(1) Considered level of exposure.

Obviously the magnitude of noisiness differences varies between low and high exposure levels and depends on the direction of view. (In Box 2, A=65 in X-noise corresponds to A=75 in Y-noise and A=65 in Y-noise to A=59 in X-noise).
Therefore empirical findings must be specified to the considered A-level. Instead of mean results, nomograms should be given which relate noisiness differences to the respective levels of both noise sources.
Box 3 gives an example, based on the (fictive) data of Box 2. Both perspectives, X to Y and Y to X are shown.

Furtheron it should be regarded that interpolations outside the studied range of A are doubtful.

Box 3

REPRESENTATION OF NOISINESS DIFFERENCES AS NOMOGRAM



(Data according to Box 2)

(2) Processing of results pertaining to different response variables.

Whereas the acoustical stimulus may be expressed by one indicator (usually L_{eq}) noise effects consist of several distinct aspects like subjective loudness, disturbance of different activities, anger, vegetative symptoms, etc. Magnitude and even direction of noisiness differences can differ with respect to these variables.

If results shall be aggregated to reflect all relevant noise impacts, methodological as well as substantative decisions are necessary:

- Which statistical type of data shall be combined? It seems favourable first to aggregate the single variables (by a standardized mode), then to compute one noisiness function per noise source, and finally to compare them. Otherwise several differences must be averaged which may be questionable.
- Shall the variables be weighted? This may be done according to statistical criteria (e.g., sensitivity, reliability, co-variance with key indicators) or to 'anthropological' relevance of various impairments. Since differences in mean and variance already work as implicit weighting in either case an explicit decision is indicated.
- Who shall decide about weights? If available, an independent group of responsible experts is very helpful, especially in case the findings are relevant for political decisions.

Additional sensitivity analyses can explicate the influence of different procedures on the final results.

4: OVERVIEW OF EMPIRICAL RESULTS.

Recently several field studies dealt with noisiness differences of environmental noise sources. Primary investigations as well as secondary analyses were conducted. Mostly road traffic was compared with one or more additional noise types; see Box 4 for an overview. (There are several further surveys, especially those on railway versus road noise). Only few studies were explicitly designed for noisiness comparisons (an example for a somewhat sophisticated approach is SCHOMER et al., 1981).

With respect to considerable methodological dissimilarities it is difficult to summarize the findings. The general tendency is as follows: Provided equal exposure levels, railway noise (especially from metropolitan lines) is less annoying than street traffic or aircrafts, while highway noise, construction noise and most of all industrial noise are more annoying compared to other sources. Partly such differences are larger at low, partly at high exposure levels. Expressed in terms of L_{eq}, differences up to 20 dB(A) have been ascertained.

Box 4

SUMMARY OF SOME EMPIRICAL FIELD STUDIES ON NOISINESS DIFFERENCES

Considered types of noise sources

S = street traffic noise
H = highway noise
I = industrial noise
A = aircraft noise
R = railway noise
C = construction noise

Study[1]	Main results concerning noisiness differences[2]	Approach[3]
FIELDS & WALKER (1980)	S >> R; A >> R	Sec.
HEINTZ et al. (1980)	S > R	Prim./Sec.
SCHOMER et al. (1981)	A > R (Night: A >> R)	Prim.
LARGE & LUDLOW (1975)	C > S	Prim.
SCHULTZ (1980)	H,S ~ A >? R	Sec.
KASTKA (1982)	I >> S; H > S	Prim./Sec..
ROHRMANN et al. (1980)	I >> C > S ~ A >? R	Prim.

Notes

(1) Further reports exist in addition to each of the cited studies.
(2) The considered annoyance criterion reflects general disturbance.
(3) Prim. = primary investigation; Sec. = secondary analysis.

5: DETERMINANTS OF NOISINESS DIFFERENCES.

Which factors determine whether noise from some sources are evaluated as more noisy, disturbing, bothersome, annoying, and so on? Some main influences are listed in Box 5.

Box 5

MAIN FACTORS INFLUENCING THE MAGNITUDE OF NOISINESS DIFFERENCES

Acoustical stimulus intensity	Acoustical moderator effects
- Type of sound measure - Selected level of exposure	- Specific sound characteristics - Temporal structure of noise
Psychological aspects of reaction	**Psychological moderator effects**
- Considered annoyance attribute - Kind of disturbed behavior	- Associations to sound attributes - Attitudes towards noise sources

(1) Methodological points.

Obviously findings on noisiness differences depend on the acoustical index - e.g., L_{eq} or L_{peak} - and even more on the behavioral criterion - e.g., cognitive or emotional reactions, affected activities or sleep disturbance, etc. - used by the researcher. Thus the comparability of studies can be very restricted (this is especially true for indirect comparisons or secondary analyses).

(2) Moderating factors.

The substantive question is which acoustical and/or psychological factors moderate noisiness. Although empirical evidence is not yet very comprehensive, two matters seem to be important:

- the temporal relation of noisy and quiet phases (e.g., duration and/or 'intensity' of noise pauses);
- attitudinal values attributed to the source (e.g., useful, dangerous, familiar, avoidable).

Furtheron general moderators of annoyance like sensitivity to noise or health concerns have a specific effect with different kinds of noise.

6: CONCLUSIONS.

Apparently an appropriate quantification of noisiness differences requires considerable methodological efforts, and the available substantive findings are not always satisfying. Thus the basis for definite legislative decisions seems still limited.

This has some consequences for further studies:

- Above all there is a necessity for conclusive "quasi-experimental" research designs (cf. COOK & CAMPBELL, 1979). The sampling should include areas with only one single noise source as well as those with two sources (enabling intra- and interindividual comparisons); an independent variation of the levels of the included noise sources is needed; the proportion of respondents with different exposure levels must be controlled; etc.

In Box 6 it is demonstrated which types of areas are relevant when a study for the quantification of noisiness differences is desired.

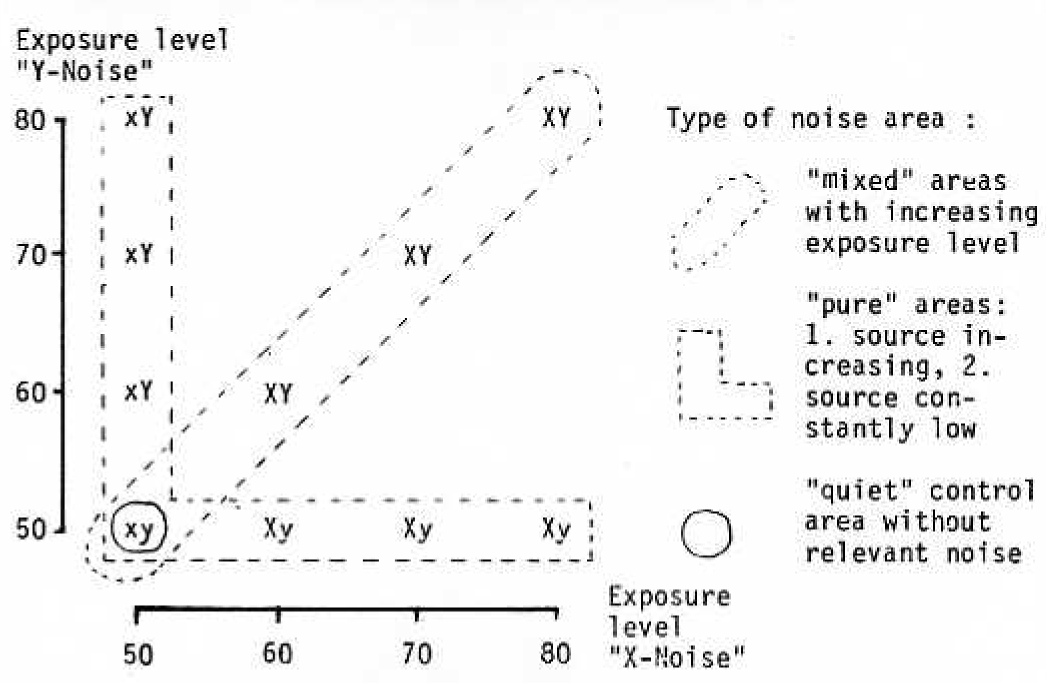
- Careful multivariate analyses are indicated to clarify the relative importance of acoustical and psychological influences on noisiness differences.

- Any decision about variables and statistical procedures - especially any averaging, aggregating, weighting, etc. - should be documented and explained.

Finally, an intensified international cooperation may facilitate such intentions.

Box 6

TYPES OF NOISE CONDITIONS RELEVANT FOR NOISINESS COMPARISONS



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