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THE RELATIVE IMPORTANCE OF NOISE LEVEL AND NUMBER OF EVENTS ON HUMAN REACTIONS TO NOISE: COMMUNITY SURVEY FINDINGS AND STUDY METHODS

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THE RELATIVE IMPORTANCE OF NOISE LEVEL AND NUMBER OF EVENTS ON HUMAN REACTIONS TO NOISE: COMMUNITY SURVEY FINDINGS AND STUDY METHODS

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SUMMARY

The data from seven surveys of community response to environmental noise are reanalyzed to assess the relative influence of peak noise levels and the numbers of noise events on human response. The surveys do not agree on the value of the trade-off between the effects of noise level and numbers of events. The value of the trade-off cannot be confidently specified in any survey because the trade-off estimate may have a large standard error of estimate and because the trade-off estimate may be seriously biased by unknown noise measurement errors. Some evidence suggests a decrease in annoyance with very high numbers of noise events but this evidence is not strong enough to lead to the rejection of the conventionally accepted assumption that annoyance is related to a $\log_{10}$ transformation of the number of noise events.

INTRODUCTION

After more than 20 years of research on community reaction to noise, many of the most basic issues remain unresolved. There is a lack of agreement about the reasons for this slow rate of progress and the methods which future research should use to resolve the issues. A research project supported by the National Research Council at the NASA Langley Research Center is attempting to consolidate existing knowledge about community response to noise while developing designs for new surveys which could provide more definitive information about fundamental research issues. This report addresses one of those central, yet unanswered, research issues; the relative importance for communities of the noise level of individual noise events and the number of those noise events. The answer to this noise and number trade-off question is of importance to policymakers who must judge the relative efficacy of policies which seek to reduce community impact by either restricting the volume of aircraft traffic or by modifying noise levels of individual aircraft.

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THE NOISE AND NUMBER TRADE-OFF ISSUE

The assumption that human response to environmental noise is a function of both the noise level of individual events and the number of events can be expressed as:

$$\text{Response} = f(\text{Level, Number}) \tag{1}$$

The noise levels are measured in decibels which are based on a logarithmic transformation of the energy contained in the noise. Most existing noise metrics assume that the number variable should also be logarithmically transformed. The relationship can then be expressed as:

$$\text{Response} = f(\text{Level}, (k)\ \text{Log}_{10}\ \text{Number}) \tag{2}$$

The noise and number trade-off research question then becomes one of determining the value of a constant ("k" in the above equation) which indicates the relative importance of noise level and number of events. Most models assume that the effects of noise level and number are additive. The constant (k) is conventionally estimated in community social surveys and laboratory studies by regressing a human response measure on noise level and number of events (ref. 1). The human response is then predicted from the equation:

$$\text{Predicted Response} = B_o + B_L(L) + B_N(\log N) \tag{3}$$

where:

- L is an average of the noise levels of the individual events
- N is the number of noise events counted
- B_o is the intercept
- B_L and B_N are the unadjusted partial regression coefficients for noise level and number of events

The entire equation can be divided by B_L:

$$\frac{\text{Predicted Response}}{B_L} = L + \frac{B_N}{B_L}\log N + \frac{B_o}{B_L} \tag{4}$$

It is then conventional to form a noise index of this form:

$$\text{Noise Index} = L + k \log N + c \tag{5}$$

where

k is the ratio of B_N/B_L

c is an arbitrarily assigned constant

This additive model with a $\log_{10}$ transformation of the number term has been the most commonly accepted model. Other models will be considered later in this report.

FINDINGS FROM COMMUNITY STUDIES

This paper is based on a reanalysis of the data from seven surveys of community response to noise. The data from five of these studies have been reanalyzed on the NASA Langley Research Center computer. Both aircraft and railway studies have been examined. Road traffic studies are not examined on the assumption that even if some type of a noise and number model is appropriate for road traffic it would differ from that for the other sources because the almost continuous noise at high road traffic volumes means that the noise does not consist solely of distinct numbers of events.

The value of "k," the noise and number trade-off term in Equation 5, has been computed for four of these surveys (refs. 1, 2, 3, and 4) in Table I. (The data from the remaining three surveys will be examined when other models are considered.) The value of "k" ranges from 23.8 for the 1961 Heathrow aircraft survey to 0.7 for the 1976 Heathrow survey. That this variation is of practical importance can be seen in the third and fourth columns of Table I. In 1961 (ref. 1), it was estimated that a doubling in number of events is equivalent to a 7.2 decibel change in noise level, but in 1976 it was estimated that a doubling in number of events is equivalent to only a 0.2 decibel change in noise level. The critical question is whether the differences between the surveys' estimates arise from real differences in the survey populations' reactions or arise from methodological differences. That there is enormous scope for the influence of unmeasured factors is evident from the last column in Table I which shows that from 80 to 90 percent of the variance in annoyance responses is unexplained by the noise level and number of event model. The remainder of this report considers whether or not methodological factors could explain the observed differences in the studies' results.

METHODOLOGICAL CONSIDERATIONS IN NOISE AND NUMBER TRADE-OFF STUDIES

This section considers six components of the methodology used in estimating the value of the noise and number trade-off. The first four concern data collection and analysis methods. The last two concern assumptions implicit in the established noise and number trade-off models. There are, of course, other differences between the surveys (a point which will be returned to later), but these six are the most critical ones for the estimation of the noise and number trade off.

Consideration 1: Method of Measuring Reactions

Human reactions in the studies in Table I are measured with standard questions in face-to-face interviews conducted by professional interviewers. Each of the first three surveys measured reactions with identical activity interference scales based on the same annoyance questions (see appendix). A separate analysis has shown that the use of a different annoyance scale in the other survey, the 1976 Heathrow survey, should not have affected the noise and number trade-off. In that analysis it was found that both scales gave similar estimates of "k" in studies where both scales were included in the same survey (1967 Heathrow and railway surveys). Based on this analysis it is concluded that no systematic differences in the four surveys' measurements of reactions could lead to the observed differences in Table I.

Consideration 2: Method of Analyzing Subjective Data

All four surveys' data are analyzed by regressing individual annoyance scores on the logarithmic average peak noise level (PNdB) of events over 80 PNdB and the logarithm of the number of noise events over 80 PNdB. All data are defined over the 12-hour period used in the original Heathrow survey (0700 to 1900) local time. The data have also been examined graphically. Because definitions and analysis methods are identical, they cannot explain differences between the surveys.

Consideration 3: Sizes of Errors in Noise Measurements

With the exception of the railway survey, no data are available on the variances of the estimates of the noise parameters. Some qualitative judgments suggest that the 1967 Heathrow noise survey data may be more accurate than the 1961 survey data (ref. 5). The possibility that errors in noise measurements could affect the estimates of the trading relationship will now be considered.

The most likely type of errors to appear would result in random errors in the measurement of the noise level. The statistical theory has been developed to describe the effects of approximately normally distributed errors which have expected means of zero. For the present exercise, however, a simulation approach is taken. In Table II, normally distributed random variables with expected means of zero and three different standard deviations ($\sigma=3$, $\sigma=5$, $\sigma=10$) have been added to the noise level data from the railway survey. (Of course, these errors are in addition to whatever errors are already present in the railway noise measurement data.) The effect of this added error is to only slightly decrease the multiple correlation coefficient ($R_{A \cdot LN}$) between annoyance and the physical noise variables. The effect on the value of k is, however, very considerable: k increases from 15, when no error has been added, to 62 when a simulated 10 dB error is added. That this effect is of substantive importance is evident in the last two columns of Table II.

The data in Table II show that random errors in measuring the noise level could account for some, if not most, of the observed differences in the value of k in Table I.

Consideration 4: The Sampling Variability of Survey Statistics

Reactions to the same noise are different for different individuals and for different study sites. Noise levels of the individual noise events vary at any one site. Because surveys only measure samples of sites, individuals and noise events, the numerical results from the surveys are only estimates of the true values of the underlying parameters. The precision of the estimates of all survey parameters can be expressed in terms of standard errors of estimateor 95% confidence intervals. None of these surveys have calculated these inductive statistics for the value of k. Estimates of the 95% confidence interval for the value of k are given for each of two different assumptions in the third and fourth columns of Table III. The third column gives unrealistically low estimates based on the simple random sampling assumption that annoyance is not affected by any study site characteristics except for the measured noise level. The fourth column gives a much wider estimate of the confidence interval on the assumption that annoyance is so strongly affected by study site characteristics as to make the true variance of estimate three times the simple random sampling variance. This great an increase in the variance has been found for some simple regression coefficients in the railway survey (ref. 7). With either set of assumptions, the broad confidence intervals for k in the 1961 Heathrow and railway surveys mean that large, potentially important, differences in the surveys' observed noise and number trading relationships must be ignored because they are not statistically significant.

The much narrower confidence intervals for k in the 1967 Heathrow survey indicate that it is possible to estimate k to a useful degree of precision. An examination of the formula for estimating the variance of k points to ways in which study design improvements can increase the precision of a survey's statistics.

The variance of k for a simple random sample (ref. 8) can be expressed as:

$$\sigma^2_{B_N/B_L} = \frac{1}{B_L^2}\left\{\sigma^2_{B_N} - 2\left(\frac{B_N}{B_L}\right)\sigma^2_{B_N B_L} + \left(\frac{B_N}{B_L}\right)^2 \sigma^2_{B_L}\right\} \tag{6}$$

where

$$\sigma^2_{B_N} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L \sigma^2_N - (\sigma^2_{LN})^2}\right)\sigma^2_L \tag{7}$$

$$\sigma^2_{B_L} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L \sigma^2_N - (\sigma^2_{LN})^2} \right) \sigma^2_N \tag{8}$$

$$\sigma^2_{B_{NL}} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L \sigma^2_N - (\sigma^2_{LN})^2} \right) \left(-\sigma^2_{LN} \right) \tag{9}$$

σ^2_e = variance of the residuals from the regression of annoyance on noise level and number

n = number of interviews

σ^2_{LN} = covariance of L and N

These formulas point to the fact that the 1967 Heathrow survey succeeded in providing more precise estimates because of a greater number of interviews ("n" in Table III), a lower correlation between number and level (r_{NL} in Table III) as well as a lower value of k.

The differences between the values of the multiple correlation coefficient for annoyance on number and level ($R_{A \cdot NL}$ in Table III) are largely irrelevant for assessing the relative precision of the studies' estimates of the trading relationships.

This analysis has clearly shown that estimates of the standard error of k are essential. At least some of the large differences in the noise and number trade-off findings are not statistically significant and thus could have arisen from sampling variability.

Consideration 5: The Assumption that Level and Number Effects are Independent

The model used up to this point assumes that the effects of level and number on human reactions are independent. This independence of effects is represented graphically in figures 1(a) and 1(b). Swedish researchers (ref. 9) have proposed an alternative model: that for high numbers of events (over 50 per day) annoyance increases steadily with noise level, while for small numbers of events, annoyance does not increase until some noise level threshold is reached (about 90 dB in figure 2). The Scandinavian aircraft study data upon which the Swedish researchers base the interaction model are shown in figure 2.

Seven studies (including the Scandinavian study) have been examined to determine whether there is evidence to support such an interaction effect. The pattern found for the U.S. aircraft (TRACOR) study (ref. 10) in figure 3 is typical of the pattern found in five of the studies (ref. 1,2,3,4,10). There is not an interaction effect. (Figure 3 averages together the data from all three phases of the TRACOR study. When the three phases are analyzed separately, the conclusions are not altered.) In none of these five studies is there support for an interaction effect. The seventh study examined is a French aircraft study (ref. 11). The data presented (ref.11) show that the interaction effect is not present in the French data when measured noise levels are used. An interaction effect only appears to be present when estimated rather than measured noise levels are used. The analysis from the Scandinavian investigation referred to above (ref. 9) which appears to support an interaction effect is also based only on estimated noise levels.

The results thus appear to be conclusive. In none of the six surveys in which measured noise levels were used could evidence be found for the interaction effect proposed by the Swedish investigators. The data support the usual assumption that noise level effects and number of events effects are independent. An interaction effect is not the cause of the disagreement between the four surveys presented in Table I.

Consideration 6: The Form of the Number Effect

The most commonly used model (Equation 5) for level and number trade off effects implicitly assumes that human response and number of events are related by a logarithmic transformation such as that in Figure 4(a).

The Swedish researchers suggest a second model, the decreasing effect model in figure 4c. They suggest that evidence for a leveling off or decline of number effects for high numbers of events is present in figure 2 where there is no more annoyance with 160 takeoffs a day than there is with 60 takeoffs a day. The cause of the similar reactions in the different number groups is impossible to assess for the Scandinavian data because the number of events is completely confounded with the airport and even country of the survey. It could be easily argued that less urban, more environmentally oriented Norweigians in Oslo are more sensitive to noise than are people in Copenhagen. Confounding of number and other area level variables' effects can be a serious problem in noise surveys based on a small number of study areas.

More convincing evidence for the decreasing or leveling off of number effects is provided by the TRACOR data in figure 3. The highest annoyance for the TRACOR sample is reached at 100 to 199 aircraft noise events a day.

A third number effect model is the linear one in figure 4b. Evidence for a linear relationship has often been thought to be provided by the 1967 Heathrow survey's finding that a higher multiple correlation coefficient is obtained for predicting reaction from an equation containing a "number" (multiple correlation coefficient of $R_{A \cdot LN} = 0.420$) as opposed to a "$\log_{10}$ number" ($R_{A \cdot LN} = 0.411$) term (ref. 1). A similar pattern was found in the railway survey: $R_{A \cdot LN} = 0.444$ for a linear form as opposed to $R_{A \cdot LN} = 0.437$

for a $\log_{10}$ transformation. In both cases, the correlational evidence is largely irrelevant since the correlations are most strongly influenced by the large numbers of interviews in low number of event situations but are insensitive to the few interviews in high numbers of event situations.

More relevant evidence about the form of the number effect can be provided with a dummy variable regression approach. (ref. 12). The results from a dummy variable regression have been used in figure 5 to represent responses normalized to an average peak noise level of 70 dB. (The five item general annoyance scale used in figure 5 is described in the appendix.) Figure 5 shows that the railway data cannot clearly support either a linear or a logarithmic relationship. The slight decrease in annoyance from 500 to 800 events a day resembles the decreasing effect, rather than the logarithmic transformation model. Given the uncertainty introduced by sampling variability, it is necessary to determine whether the observed decrease in annoyance with higher numbers of events is significantly different from the increase in annoyance which would be predicted from a logarithmic model. A critical test of this hypothesis is provided by examining the difference between the observed average annoyance for the respondents between 600 and 1000 events a day and the annoyance which is predicted (using respondents below 600 events a day) from the regression of annoyance on average peak noise level and $\log_{10}$ number. The difference in annoyance scores of 0.5 has a quite low statistical significance ($p \simeq 0.40$) even with simple random sampling assumptions. A similar pattern emerged from an analysis of the 1967 Heathrow data.

Six of the seven surveys examined (the exception being the 1961 Heathrow survey) exhibit a pattern in which there is slightly less annoyance for the highest number of event groups. Like the railway survey, however, the evidence from each survey is quite weak. If the surveys' results converged by sharing a common turning point at which increases in numbers of events lead to decreased annoyance then the combined evidence would be quite strong. Table IV indicates that the surveys do not give a similar numerical value for such a turning point. An examination of the "Definition of Number" column in Table IV shows that the number definitions are so different as to make comparisons between surveys meaningless at even moderately low noise levels. For example, noise events from landing aircraft with 75 dB(A) peak noise levels would have been counted in the TRACOR and Heathrow surveys but not in the Scandinavian or French surveys. For areas with moderate level aircraft noise events the rules for counting the numbers of events are largely arbitrary. None of the number definitions attempts to actually estimate the number of planes which could be heard in areas with different ambient noise levels.

Effects of Other Discrepancies

Community surveys differ from one another in more than only the six aspects described in this report. Some of these other aspects probably affect the populations' responses to noise. While these facts certainly introduce uncertainty into the comparisons made here, they do not by themselves invalidate the comparisons. The only critical aspects to be considered in the estimate of a noise and number trade-off statistic are those which would affect the value of that statistic. While this report has not provided an exhaustive list of variables which could affect noise and number trade-off estimates it does identify some very important ones. The enormous uncertainties which this report has found to be introduced by the unknown noise measurement errors and the imprecise estimates of the noise and number trade-off would remain and invalidate any attempted comparison which controlled for other differences between the surveys.

CONCLUSIONS

In the seven studies analyzed here, as well as in five other studies for which only the reports could be examined (refs. 13, 14, 15, 16, 17), it is found that the number of noise events is related to annoyance. No definitive evidence was found on the exact form of the relationship between human response and number of noise events. There is fairly consistent, though weak, evidence for a decrease in annoyance for high numbers of noise events. This evidence is not, however, strong enough now to disprove the widely accepted assumption that annoyance is directly related to a logarithmic transformation of the number of noise events. A constant noise level and number of event trade-off may thus be valid over only a restricted range of number of events. No survey suggests that the value of k (Equation 5) for the noise and number trade-off is greater than 25. Given the probable effect of noise measurement errors, it would appear that the value of k is most probably less than 10. No evidence was found to support the noise level and number of event interaction model suggested by the Scandinavian aircraft noise model.

New field studies of the trade-off effects of noise level and number of noise events on annoyance will only be valuable if new approaches are taken in designing and gathering data. The accuracy of the physical noise measures must be specified. The precision of all statistics linking human response to the noise environment should be specified with techniques which take into account a study's complex sample and noise measurement design. Alternative, meaningful definitions of numbers of events should be measured and analyzed. Levels of individual events and number of events should not be too highly correlated. Numbers of events must not be seriously confounded with other area characteristics.

APPENDIX

Annoyance Measures

1. The annoyance measures used in the British studies were defined using the questions listed here. These questions are presented as they appeared in the railway survey. Questions appearing in the Heathrow survey substituted the work "aircraft" for the word "train." Following this list, the way in which the multiquestion scales were constructed has been indicated.

Q 10.a Coming back now to your house/flat. When you are indoors, do you ever hear ..... trains? (No = 1)

b Does noise from .... trains .. bother or disturb or annoy you at all? (No = 2, Yes = 3)

Q 11.b In particular, how do you feel about the amount of noise here from <u>passenger, goods & other trains</u>? (SHOW CARD D)

Definitely Satisfactory 1 to Definitely Unsatisfactory 7

Q 17.a REFER TO Q 10.a: Can I just check, you said you did/did not hear train noise here? (Not hear = 1)

b Does the noise of the trains bother or annoy you (5)Very much, (4)Moderately, (3)A little, (2)Not at all.

Q 18.a Do the trains ever ..... (READ FROM LIST)
<u>IF YES, THEN ASK</u>

b When they .... how annoyed does this make you feel? Very, moderately, a little or not at all?

ASK (a) THEN (b) FOR EACH ITEM IN TURN

Wake you up?
Interfere with listening to radio or TV?
Make the house vibrate or shake?
Interfere with conversation?
Interfere with or disturb any other activity?
(SPECIFY ALL. ASK b) OF MOST ANNOYING)

Q 43.a If you had the choice, would you rather live in a place where there was no railway noise at all, or in a place where you could sometimes hear some noise from the railway?

Q 43.b Here is a scale showing the different amounts of railway noise that there might be in an area, (SHOW CARD G1 IF CODE 1 ABOVE, CARD G2 IF CODE 2 ABOVE) What number would you pick to rate the place where you live now?

(G1: No railway noise at all)
(G2: The amount of railway noise that would be perfect for you) 10
9
8
7
6
5
4
3
2
The worst imaginable amount of railway noise 1

Q 61. Now, just to be sure that I have it all straight. How do you feel about the amount of noise here from <u>passenger, goods, and other trains?</u>
(SHOW CARD J)

Definitely satisfactory 1
2
3
4
5
6
Definitely unsatisfactory 7

2. The Guttman activity interference scale was created with the scoring used in the Heathrow studies except that the railway questionnaire only included the first of the two probing "other" type of question. (This should not affect the results since only 6% of the Heathrow respondents gave an answer to the second probe.) This scale is used in Tables I, II, and III for the railway survey and the 1961 and 1967 Heathrow surveys. The scale was created by summing the answers to 6 questions by giving a score of one for each of the following answers:

	Question	Answers scored 1
Q17.b	Overall annoyance	Very, moderate, a little,
Q18.b	If wake up	Very, moderate
	radio, TV	Very, moderate, a little
	vibration	Very, moderate, a little
	conversation	Very, moderate
	other activity	Very, moderate, a little

3. The 1976 Heathrow survey results in Tables I, II, and III are based on a question using the response alternatives presented in Q 17.b (above) scored as follows: (1) not hear or not at all annoyed, (2) a little annoyed, (3) moderately annoyed (4) very much annoyed.

4. The index from the five overall annoyance scales (used in figure 5) was created by taking the average score for the questions on which respondents had valid data. The numerical codes shown above were transformed in the following way before being averaged:

Q 10.a & b	(((Q10.a&b -1)/2)x10)+1
Q 11.b	(((Q11.b -1)/6)x10)+1
Q 17.a & b	(((Q17.a&B -1)/4)x10)+1
Q 43.b	(11 - Q43.b)
Q 61	(((Q61 - 1)/6)x10)+1

5. The Swedish investigators report that the high annoyance response used in figure 1 can be translated from Swedish, Norwegian, and Danish into English as "very annoyed."

6. The TRACOR study's definition of "highly annoyed" is based on a dichotomous division of activity interference annoyance scales.

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TABLE I.- OBSERVED NOISE AND NUMBER TRADE-OFF IN FOUR SURVEYS

Survey	k	Indications of Trade-Off Relationship		Unexplained Variance
		1 dB is equivalent to increase in N of	Doubling of number is equivalent to an increase of	
1961 Heathrow	23.8	10%	7.2 dB	80%
1967 Heathrow	4.1	76%	1.2 dB	83%
Railway	14.8	17%	4.5 dB	89%
1976 Heathrow	0.7	317%	0.2 dB	90%

TABLE II.- EFFECT OF RANDOM ERROR IN NOISE LEVEL (RAILWAY SIMULATION)

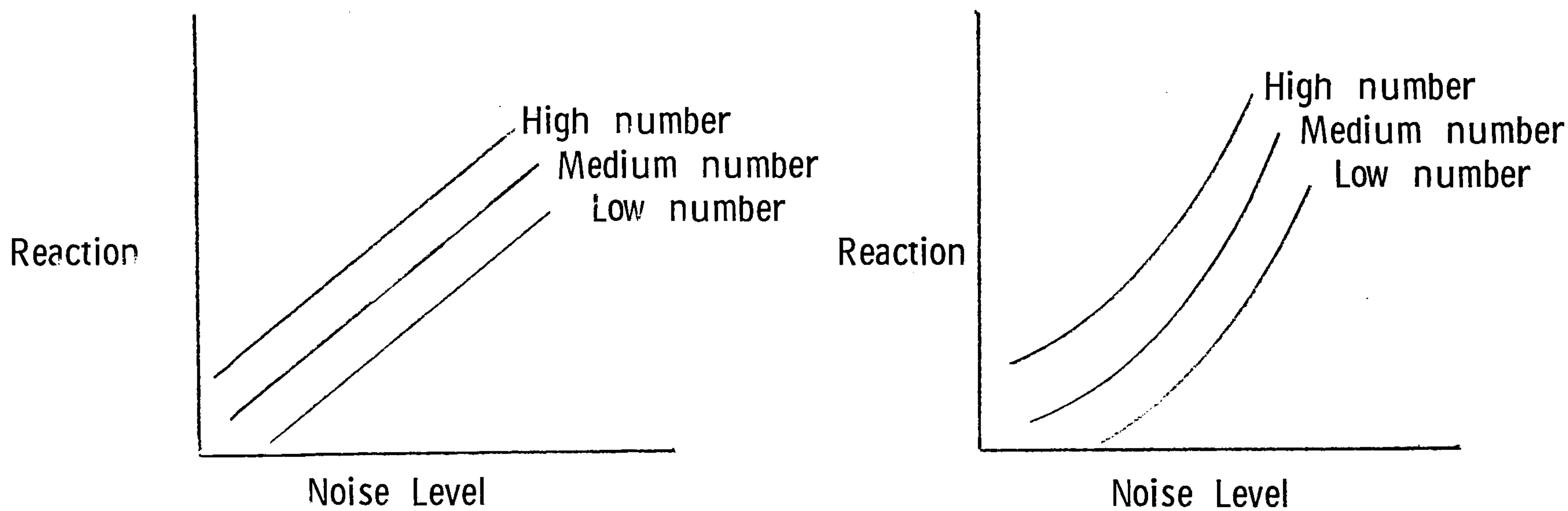
σ of Added Error	$R_{A \cdot LN}$	k, $\frac{B_N}{B_L}$	1 dB is equivalent to increase in N of	Doubling of number is equivalent to an increase of
None	.34	15	17%	4.5 dB
3	.32	22	10%	6.6 dB
5	.31	36	7%	10.8 dB
10	.30	62	4%	18.7 dB

TABLE III.- PRECISION OF ESTIMATES OF "k"

Survey	k	95% Confidence Interval: Based on simple random sampling assumptions	95% Confidence Interval: Assuming true variances of estimate are three times the simple random sampling variances	$R_{A \cdot NL}$	r_{NL}	n
1961 Heathrow	24	11 to 37	2 to 46	.45	.70	1731
1967 Heathrow	4	3.3 to 4.9	2.7 to 5.4	.41	.29	4655
Railway	15	7 to 23	1 to 28	.34	.46	1154
1976 Heathrow	1	-2 to 4	-4 to 6	.32	.63	2618

TABLE IV.- TURNING POINTS FOR NUMBER EFFECTS FOR FIVE STUDIES' NUMBER DEFINITIONS

Study	Turning Point for Number Effect	Definition of Number
Scandinavian	50	Departures over 70 dB(A) - Nominal Contour
French	45	Events over 80 dB(A)
Heathrow (1967)	300	Events over 66-68 dB(A)
Railway	600	All Events on Route
U. S. - TRACOR	100-200	All Movements "Over or Near" Site



(a) for linear relationships

(b) for curvilinear relationships

Figure 1.- Independence of level and number effects.

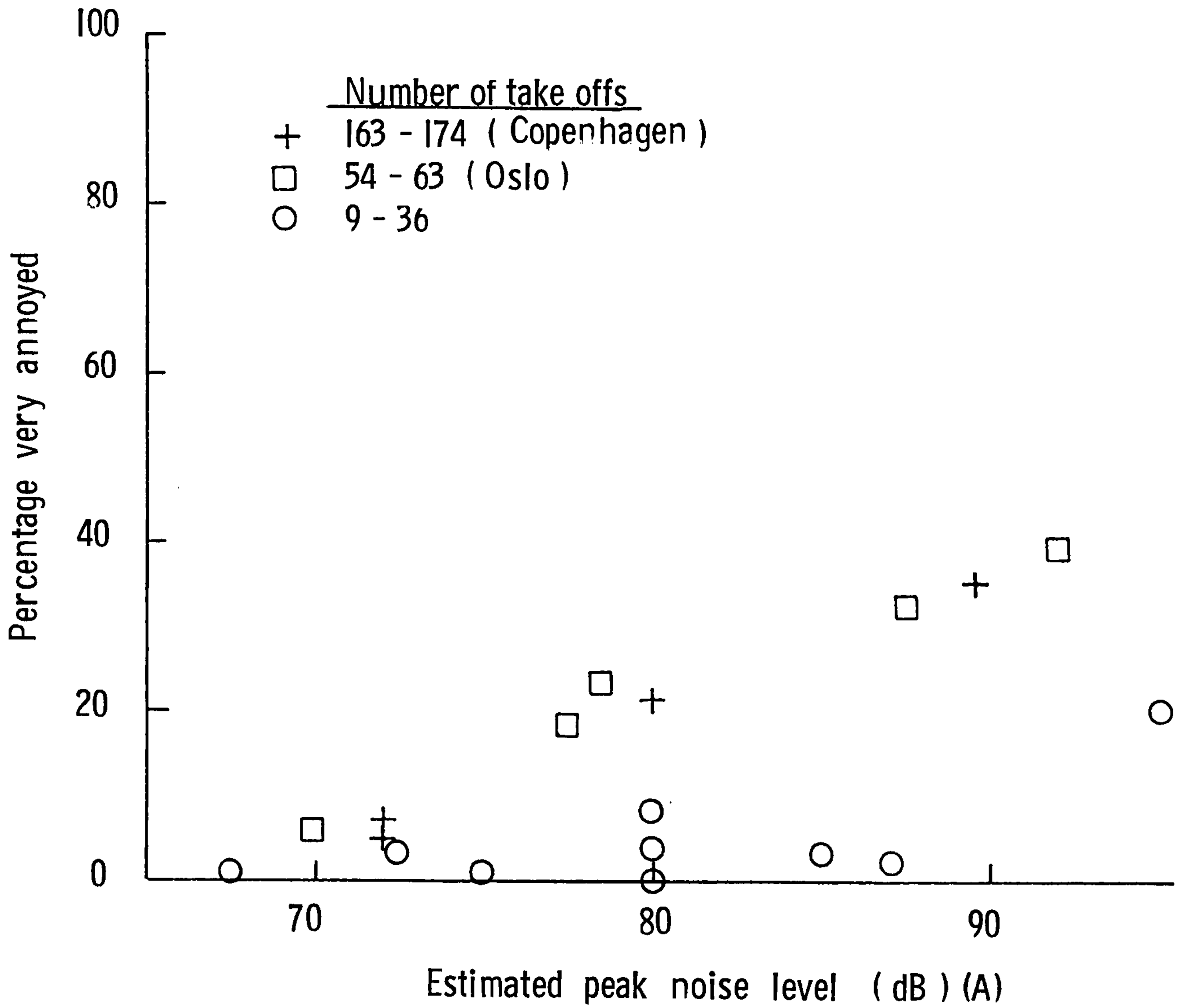


Figure 2.- Scandinavian aircraft noise reactions in number groups.

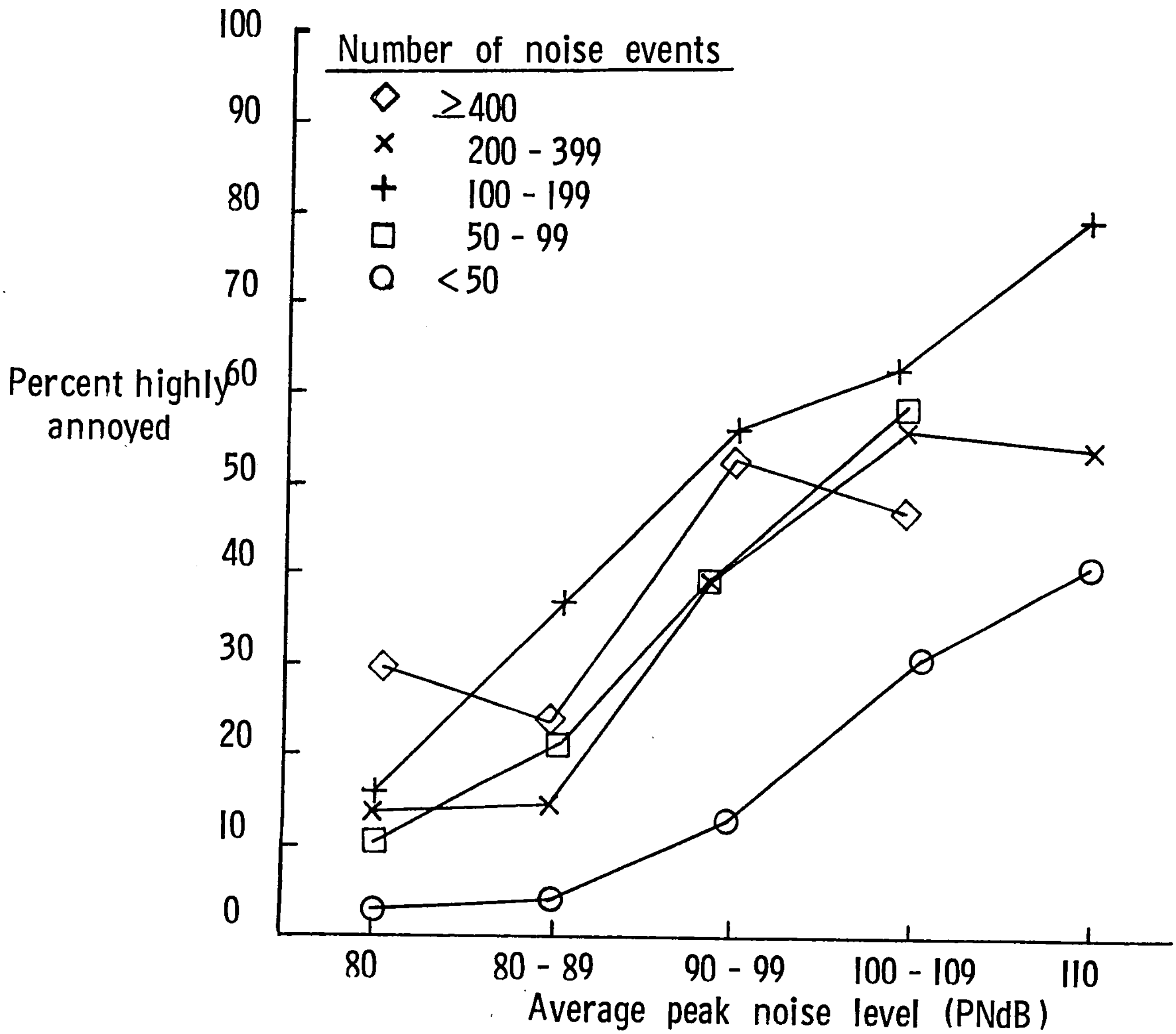
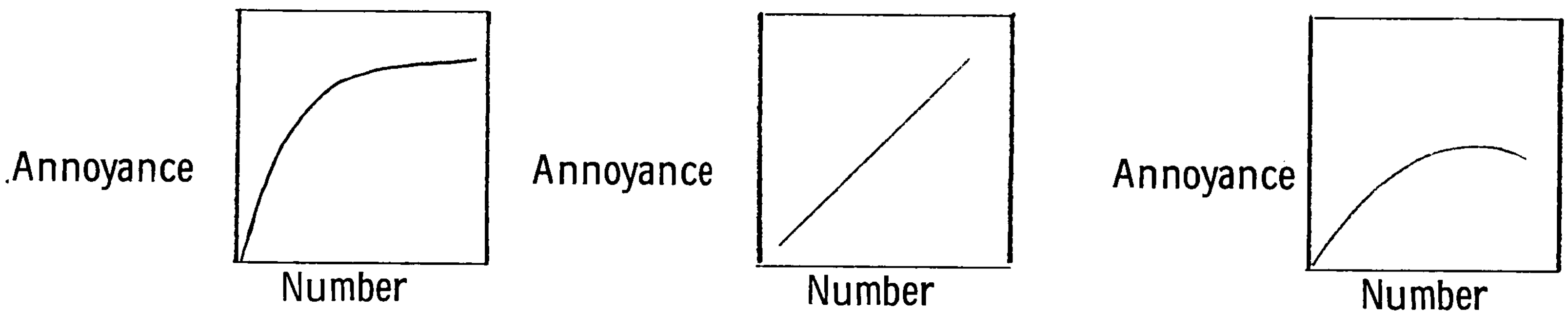


Figure 3.- TRACOR aircraft noise annoyance in number groups.



(a) logarithmic effect model (b) linear effect model (c) decreasing effect model

Figure 4.- Alternative models for the number effect.

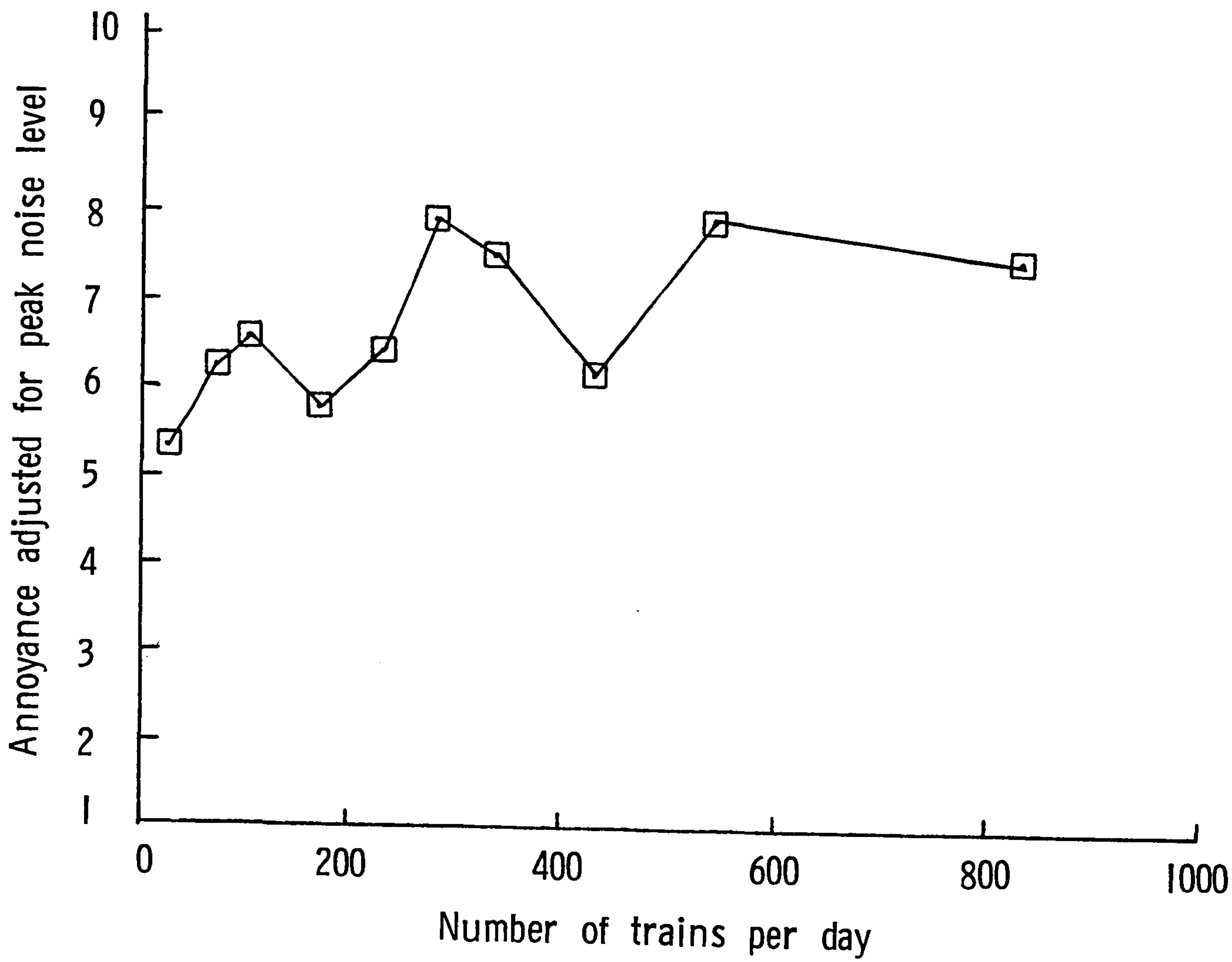


Figure 5.- Effect of number of trains on reactions to railway noise.

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16. Abstract

The data from seven surveys of community response to environmental noise are reanalyzed to assess the relative influence of peak noise levels and the numbers of noise events on human response. The surveys do not agree on the value of the trade-off between the effects of noise level and numbers of events. The value of the trade-off cannot be confidently specified in any survey because the trade-off estimate may have a large standard error of estimate and because the trade-off estimate may be seriously biased by unknown noise measurement errors. Some evidence suggests a decrease in annoyance with very high numbers of noise events but this evidence is not strong enough to lead to the rejection of the conventionally accepted assumption that annoyance is related to a $\log_{10}$ transformation of the number of noise events.

17. Key Words (Suggested by Author(s))
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