On Fitting Functions to Data for the Percent of a Community Highly Annoyed to Noise such as Impulsive Noise.

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Abstract: Survey respondents "highly annoyed" (HA) typically are categorized as those responding in the top 27 to 29 % on an anchored numerical scale or in the top two categories on an adjectival scale. The percent HA typically ranges from 0 to 40 percent. At higher percents HA (e.g., >15 %), the noise stimulus is clear and dominant and the reliability to the percentage values is high. At low percentages, the reliability is low. Some respondents may be annoyed any time they hear a sound. Depending on the number of such respondents, the percent HA can vary greatly on a percentage basis (4% HA versus 2% HA is a change of 100 %). Therefore, one possible alternative to using small percentages HA (e.g., <10%) is considered for fitting transition functions to HA data. This method is to avoid small percentages HA by considering the group "little annoyed" or "happy." This category might include the bottom two categories on a 5-point adjectival scale or the bottom 27 to 29 % on a numerical scale.

THE PROBLEM

Currently, there is great interest in being able to assess sounds with special character such as impulsive sound along with more common sounds such as the sound generated by traffic. For example, under an initiative by the European Union, all sound in every area of the EU would be mapped using one common noise metric. To accomplish this mapping, it is necessary to "equate" some measure of impulsive noise to an "equivalent amount" of a reference noise—say traffic noise.

The best measure of response developed to date appears to be the quantity "highly annoyed." Schultz (1978) developed this measure. Highly annoyed is typically defined as the top 2 adjectives out of the 5 adjectives for annoyance: *not at all, a little, moderately, very much,* and *extremely*; or it is defined as the top 27 to 29% on a numerical scale that is anchored at the ends by something like the annoyance adjectives: *not at all* and *extremely*. Figure 1 illustrates Schultz's results. With this function, one can relate a percent of a typical community that will be highly annoyed at a given sound level. For example, if the day-night sound level (DNL) equals 60, then 18 percent of the typical community is highly annoyed. It is natural to consider this measure, highly annoyed, as the means to relate one noise environment to another; i.e., it is natural to want to use the percent highly annoyed to relate impulsive noise to traffic noise. If, for a certain measure of impulsive noise, the percent of the community highly annoyed is 18 percent, then it is natural to relate that measure of impulsive sound to an equivalent traffic noise environment where the DNL is 60 dB.

Equating the percent highly annoyed to find the equivalence between some measure for impulsive sound and equivalent A-weighted road traffic sound should work well when the percentages are sufficiently large. Schultz, in his analysis, speaks of the data range as being "above 50 DNL." Clearly, Figure 1 shows that most of the data were above 50 dB. Schultz was concerned with the choice of a DNL level below which the percent highly annoyed was to be zero. He chose 35 dB but stated:

> "The best fit to most of the data was found for a quadratic equation with a choice of L_0= 35 dB; alternative choices of 40 and 45 dB for L_0 made very little difference, in ht noise level range occupied by the data points, particularly for high noise levels. The greatest differences occurred outside the survey data range, between 35 and 50 dB…"

This discussion and the data in Figure 1 suggest that the method of equating percent highly annoyed to find equivalencies should only be used when the DNL exceeds 50 to 55 dB. Above this threshold, the percentages are becoming reasonably large numbers and can be expected to be stable. Below 50 dB, the percentages highly annoyed are very small numbers, subject to large variation just by the curve fitting technique used, and possibly subject to large variation just because there may or may not be a few subjects included that are "always annoyed if they just hear the sound." It would take only a few "always highly annoyed" subjects to cause a large percentage change in a very small number. For these reasons, the method of equating percentages highly annoyed should only be used when the DNL exceeds about 55 dB.

As a further illustration of the problem, Table 1 shows the results of Monte Carlo simulations of survey results. The simulation assumes a 5-level adjectival scale for annoyance. Highly annoyed is defined to be the top 2 categories. The subjects respond with a sigma of 1 category. The ideal results have a sharpness that is equivalent to the Schultz relation in the range from 55 to 75 dB. It is assumed that the dose ranges from 45 to 75 dB in 5 decibel steps and that the 50 percent point is at 70 dB. Simulations are performed with 25, 100 and 1000 subjects. Each simulation is repeated 5 times. Table 1 shows the maximum and minimum percent highly annoyed at each of the seven dose levels. These numbers are given for each size of survey. It should be emphasized that this demonstrates only the random variation—not the systematic bias of those that are always annoyed at any audible level. As expected, the relative error goes down with increasing dose level (increasing percent highly annoyed) and with increasing number of survey respondents. With 25 subjects, the errors are potentially very large until the percent highly annoyed exceeds about 50 percent, with 100 subjects, until the percent highly annoyed exceeds about 25 percent, and with 1000 subjects, the errors are potentially very large until the percent highly annoyed exceeds about 2 percent. Note that the range in the table is quite similar to the range in Figure 1.

Number/ Dose	25	100	1000
45	0/8	0/1	0.7/1.2
50	0/8	0/2	**1.5/2.1**
55	0/8	1/3	**2.5/3.4**
60	4/8	4/7	**3.6/5.4**
65	8/20	9/16	**11/13**
70	16/40	**23/30**	**28/33**
75	**52/72**	**57/71**	**57/61**

TABLE 1. Minimum and maximum percent highly annoyed for 5 repeated simulations with three different sample sizes.

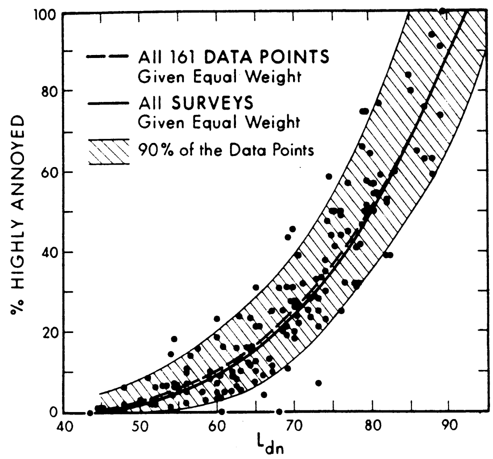

FIGURE 1. Schultz relation for percent highly annoyed (from Ref. 2, Figure 6).

ONE POSSIBLE SOLUTIOIN

What then should be used to equate situations when the DNL is small? One suggestion is offered herein. This method would involve the creation of a new descriptor that would mirror "highly annoyed." We suggest the term "percent basically happy." This term would be subjects responding in the bottom two annoyance categories out of the 5 adjectives for annoyance or responding in about the bottom 27 to 29 % when using an anchored numerical scale to describe annoyance. At low noise levels, the percent happy should be large numbers and relatively stable. A few more or less subjects that are always highly annoyed will not change the percent happy by any significant amount. The basic rule for finding equivalencies might be that if most of the (equivalent) DNL levels are above 60 dB, then percent highly annoyed is the measure to use to equate differing sound environments. But if most of the (equivalent) DNL levels are below 60 dB, then percent happy is the measure to use. If the data span a very wide range, then both methods should be used.

In summary, percent highly annoyed is an unstable and unreliable method to find equivalencies between two differing noise environments when the percentage are small. A method should be used that is not sensitive to large potential errors in small values for highly annoyed. One method would be to substitute the percent happy for the percent highly annoyed when the DNL levels are small. A second method would be to fit a transition function to percent highly annoyed data by finding two or possibly three independent parameters.

REFERENCES

1. European Commission Green Paper, *Future Noise Policy*, Brussels (1996).
2. Schultz, T.J., *J. Acoust. Soc. Am*., **64**(2), 377-405 (1978).