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TOTAL ANNOYANCE AND PERCEPTUALLY DISCERNIBLE NOISE SOURCES

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ABSTRACT
Questionnaire-study respondents typically attribute their annoyance to specific sounds. Obviously, these sounds can be discerned perceptually in the flow of sounds constituting the soundscape but also be integrated into total annoyance reports. Current total annoyance models integrate sound pressure levels or annoyances of singular noise sources. Total annoyance models based on energy summation for multiple noise sources are incompatible with empirical field data that unavoidably involves perceptual-cognitive integration. In a field study involving cars, buses, trucks, and MCs, total annoyance was found to be less than source specific annoyance, indicating compromise. A multiple regression equation was used to model this kind of integration and the weights were found associated with the relative "on time" of the various noise sources.

1 - INTRODUCTION
Proposed total annoyance models are psychophysical or perceptual in nature [3]. Psychophysical models describe total annoyance as a function of acoustical variables whereas perceptual models describe total annoyance as a function of perceptual variables. For both, total annoyance is given with regard to singular noises from two or more different sources. Proposed models are not founded on knowledge about psychological processes involved in the formation of annoyance, but are rather "abstract" mathematical constructs of "total annoyance". It seems that valid models require that relevant psychological processes are understood and incorporated in the models. One way to do this is to study the perception of the noise immission and try to reveal relationships between the partial, source-specific annoyances and the total annoyance.

2 - TOTAL ANNOYANCE MODELS
Noises within the total sound environment are perceived as separate events, which may occur simultaneously, but more often occur time-separated. Respondents perceive these events as source specific [7]. The noise from these sources are more or less annoying. Total annoyance is believed to be integrated from the various source specific annoyances. In field studies, source specific annoyances are based on how noises are perceived *within* the total sound environment, rather than to the annoyance (or L_{eq}) they would have had if they occurred alone (singular noise). Models of total annoyance as a function of source specific annoyances have been theorized about [2], [8, 9] and have been empirically tested on laboratory data [4].
In field studies, total annoyance is often reported to be less than source specific annoyance. This phenomenon is called "compromise" or "averaging" strategies [5]. Such a finding seems contradictory because total sound level can never be less than the sound level of a single source within the total sound. Therefore, the validity of total and source specific annoyance reports obtained in field studies have been questioned [6]. However, human evaluation of complex objects always involves integration of various pieces of information. Compromise is not an unusual or incomprehensible psychological phenomenon. For instance, "averaging" models are needed for explaining likableness of a given person because likableness of his/her most prominent virtue is typically stronger than the overall likableness [1]. Similarly, the

overall impression of a "poor" motion picture (cf. total annoyance) may be better than the impression of its worst actor (cf. most annoying noise source).

3 - EMPIRICAL RESULTS FROM A FIELD STUDY

In a questionnaire study, residents living close to a main road were asked about total annoyance and source-specific annoyances as experienced during the last month. The road-traffic consisted of approx. 91 % light vehicles (car), approx. 7 % heavy vehicles (truck, bus) and approx. 2% motorcycles (MC). One evening a week, the proportion of MCs was approx. 7 %, at other times it was less than 1 %.
Annoyance was reported on an analogue scale from "not at all annoying" (=1) to "extremely annoying" (=7). Table 1 gives means (and dispersions) of annoyances for two groups of respondents: residents living <50 m from the road (N=135) and residents living >50 m from the road (N=365), at most 300 m. Total annoyance is given in Column 2 and source specific annoyance to cars, buses, trucks and MCs in Columns 3, 4, 5, and 6, respectively.
MCs were the specific source with the greatest mean annoyance (Column 6, Table 1). For both resident groups, the mean source specific annoyance for MCs was *greater* than the mean total annoyance (cf. Column 6 & 2) and less so for trucks (cf. Column 5 & 2). MC-annoyance was greater than total annoyance for 81 % of the residents living close to the road and for 62 % of those living farther away. Corresponding percentages were for truck 41 % and 34 % and for cars and buses less than 25%. Thus, only MCs show compromise in the majority of the residents.

Residents	Arithmetic Mean (Standard Deviation) of Annoyance				
Living	Total	Cars	Buses	Trucks	MCs
<50 m from the road*	4.7 (1.3)	4.4 (1.2)	4.5 (1.6)	5.2 (1.3)	6.2 (1.0)
>50 m from the road**	3.0 (1.4)	3.0 (1.5)	2.7 (1.5)	3.2 (1.6)	4.2 (1.8)

Table 1: Road-traffic noise annoyance in a questionnaire field study (MC=motorcycle; *N=135; **N=365).

Noise from MCs was predominant once a week only. Removing the MCs totally from the road traffic does not significantly change the 24-hour equivalent continuous sound level although the MC was the most annoying specific source. It seems that source specific annoyance is mainly influenced by the "on-time" of the noise from the specific source. Thus, even though noise from MCs are absent most of the time, their annoyance is high when they are present and this is what the residents are reporting. Conversely, total annoyance includes "on-time" for noise from many sources as well as for more quiet periods. The residents have to consider both and, thus, may choose several strategies for total annoyance, for example, "arithmetic summation", "arithmetic averaging" or "strongest component".

4 - MODELING TOTAL ANNOYANCE IN A FIELD SITUATION

A simple multiple regression model may describe total annoyance as the weighted sum of source specific annoyances, Equation 1.

$$\Psi_{\text{total}} = w_1\Psi_1^{'} + w_2\Psi_2^{'} + \ldots + w_n\Psi_n^{'} + R \quad (1)$$

where Ψ_{total} refers to total annoyance, $\Psi_i^{'}$ refers to specific annoyance of source i as heard within the total sound environment, w_i is a weight unique to each source i, and R is a constant that stands for the annoyance of residual noises. If all weights are set to one, Equation 1 corresponds to the arithmetic sum. This would mean that total annoyance is never less than source specific annoyance. However, if the weights are less then one, the model would allow for compromise. Although Berglund and Nilsson [4] showed that pairs of traffic, train and aircraft noise approximate Euclidean summation for loudness, the multiple regression model is applied here for total annoyance because it is a simple and easily comprehensible model suitable for illustration. In addition, it is particularly suitable for describing the joint partial contributions to total annoyance of the specific source annoyances as assessed *within* the "same" sound environment.
The multiple regression equation was fitted to the annoyance values of the whole data set of the questionnaire study (1 total and 4 source specific annoyance reports from each of 500 residents). The following weights of Equation 1 were obtained: w_{car}= 0.39, w_{bus}= 0.18, w_{truck}= 0.18, w_{MC}= 0.14 (R=0.25; r^2=0.73). The car-annoyance obtained higher weights than the two most annoying sources (MC, truck).

Although cars were not scaled as the most annoying noise source, the car annoyance values explained most of the variance in total annoyance.
The rank-order of the weights obtained for the specific sources reflects their "on-time", which was longest for cars and shortest for MCs. Total annoyance may, thus, be modeled as a function of the "on-time" of specific noise sources and their corresponding annoyances [cf. 10]. Such a model can utilize source specific and total annoyance obtained in field studies. Models could be developed to include relationships between acoustical properties of specific sources and their annoyance. Combined with knowledge of the time during which such sources are *heard*, total annoyance may be better predicted from acoustical properties only. However, to be successful, psychophysical models have also to incorporate the relationship between source specific exposure and perceptual identification of sources, as well as, interactions between simultaneous noise sources (e.g. due to masking). So far, knowledge is lacking. Therefore, total annoyance is best evaluated perceptually in the sound environment.

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