
SHORT COMMUNICATION

Assessment of Odor Annoyance and Its Relationship to Stimulus Concentration and Odor Intensity

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Abstract

Results from the present study suggest that magnitude estimation of odor annoyance shows acceptable reliability and that it generates stable individual psychophysical power functions with relatively similar exponent sizes between subjects.

Introduction

Psychophysical approaches have been demonstrated as valid and applicable to a wide range of issues concerning sensory reactions to environmental chemical exposure, including sick-building syndrome, exhausts from combustion engines and industrial pollution (e.g. Berglund and Lindvall, 1986; Martin and Laffort, 1996). Among a broad variety of potential perceptual and somatic reactions to chemical exposure, odor annoyance is in this respect a very common complaint (Springer, 1974; WHO, 1987) and has been pointed out as an important component of an early warning system (Baird *et al.*, 1990).

Annoyance can be defined as a feeling of displeasure associated with any agent or condition believed to have an adverse effect (Lindvall and Radford, 1973). The concept is complex and may be considered as a perception, an emotion, an attitude or a mixture of these (Berglund *et al.*, 1987), although these concepts have not yet been evaluated individually. With this complexity in mind, it is not surprising that personal factors have been shown to influence odor annoyance, including age (Steinheider and Winneke, 1993; Zeidner and Shechter, 1988), gender (Deane and Sanders, 1978) and attitude toward pollution source, and to industry and authorities in general (Evans *et al.*, 1988). Other important factors include intensity (Cavalini *et al.*, 1991), frequency (Hangartner and Wuest, 1994; Steinheider and Winneke, 1993) and quality (Winneke and Kastka, 1987) of the exposure.

Although methodological issues have been studied in

sensory irritation to aromatic compounds, less attention has been directed towards the reliability and validity of assessing odor annoyance, and in particular regarding the relationship between odor annoyance and stimulus concentration. Considering the relatively large body of work on odor intensity, we found it to be of particular interest in the present study to approach annoyance in the light of intensity. For this, pyridine was chosen as the aromatic compound since it has both olfactory and trigeminal properties, is generally perceived as annoying even at moderate intensities, has a relatively low potency for adaptation and has been used in a number of previous environmental studies.

The present work addressed several questions related to odor-annoyance assessment, including the reliability of magnitude estimates by comparing annoyance and intensity of odors with respect to variability across repeated measurements. It was also investigated how well annoyance can be described as a psychophysical power function of stimulus concentration. Yet another question referred to whether the interindividual difference in slopes of psychophysical functions differ between annoyance and intensity. We were also interested in studying a possible intermodal consistency within the subject between annoyance and intensity that may be perceptual and behavioral in nature. Hence, we examined whether subjects who generate large exponents of psychophysical power functions and large goodnesses-of-fit

to these functions for odor intensity also tend to do so for annoyance.

In assessment of environmental perception it is often necessary to use different observers for judging different stimuli and still wanting to construct a scale of a defined unit of measurement. Berglund and Lindvall (1979) therefore developed the concept of master scaling in which a group of subjects use magnitude estimation to judge the perceived magnitude of a reference stimulus with several intensities jointly with the perceived magnitude of the target stimulus (e.g. the environmental pollutant). The empirically obtained psychophysical power function for the reference stimulus is then transformed to a master function. Using these very same transformation factors, the empirically obtained perceived-magnitude values for each target-stimulus intensity is then transformed and expressed as the perceived magnitude of the target stimuli (Berglund, 1991). The need to establish a master-scale equation of odor annoyance was addressed in the present study.

Methods

Sixteen adults, seven men and nine women participated, aged 30–55 years (mean = 41.0). One subject reported being a smoker, but all reported normal odor sensitivity.

Seven pyridine concentrations were presented with an olfactometer, ranging from 250 to 16 000 ppb (twofold increments) and obtained by dilutions of pyridine in deionized water (5.0×10^{-6} – $3.3 \times 10^{-4}\%$). Gas-phase concentrations from 50 ml of the pyridine solutions, kept in 2 l glass bottles, were determined by gas chromatography. Each test bottle was connected through a glass tube to an identical back-up bottle to shorten the time of equilibrium. All bottles were also equipped with two-way polyethylene/polypropylene valves, silicone rubber/polycarbonate respirator masks (Respironics Contour Mask™) and silicone rubber stoppers (Lidén *et al.*, 1997). The experiment was performed in a laboratory with forced ventilation (25 air-exchanges/h). The air temperature was kept at 21°C (SD = 0.7) and relative humidity at 32% (SD = 1.9).

Odor intensity and odor annoyance were studied separately with an interval of 1–8 days (mean = 2.6). Eight subjects participated first in the intensity condition followed by the annoyance condition, the remaining eight subjects participating in reverse order. Prior to the first condition, subjects were given practice in magnitude estimation [the ratio of the numbers between stimuli corresponds to the ratio of the perceived magnitude between stimuli (Stevens, 1975)] by being asked to judge the lengths of seven lines presented seven times each, ranging from 20 to 140 mm in length. A prerequisite for participation was that the subject was able to perform the estimation task for line length. The criteria used were an exponent of the psychophysical power function of 0.7–1.3 [shown in previous studies to approach unity (Hellman and Meiselman, 1988; Stevens and Guirao,

1963)] and a goodnesses-of-fit > 0.95, based on previous use of these criteria (Nordin, 1994).

Each of the seven pyridine concentrations were judged seven times, once in each of seven sessions (latin square design). To calibrate the subjects with respect to inter-individual homogeneity and intraindividual variation, all sessions started with presentation of a 2000 ppb standard stimulus (modulus) of pyridine, with the instruction to assign it the magnitude estimate of 100. The interval between sniffs was at least 12 s and each session lasted ~3 min, with an interval between sessions of ~4 min.

Intraindividual coefficients of variation (SD/mean) for annoyance and intensity were calculated for each pyridine concentration and averaged across subjects. Individual psychophysical power functions were obtained for each modality by averaging estimates across stimulus repetitions for each stimulus magnitude. Regression lines were fitted to the averaged estimates and corresponding stimulus magnitudes (log–log units) by the method of least squares. Group psychophysical power functions were obtained for annoyance and intensity by averaging across the subjects' averaged estimates for each pyridine concentration. Inter-modal power functions (odor annoyance as a function of odor intensity) were obtained for each subject and for the group by averaging the magnitude estimates and fitting a regression line in the same manner as for the psychophysical functions.

Results and discussion

Variability in magnitude estimates

The results on intraindividual coefficients of variation for annoyance and intensity suggest that although there is a tendency for a larger variation in annoyance than in intensity within a laboratory setting, as illustrated in Figure 1, the difference is not statistically significant. A two-way (modality by concentration) analysis of variance with repeated measures across modalities and concentrations shows no significant effect of modality [$F(1,15) = 3.91$] or

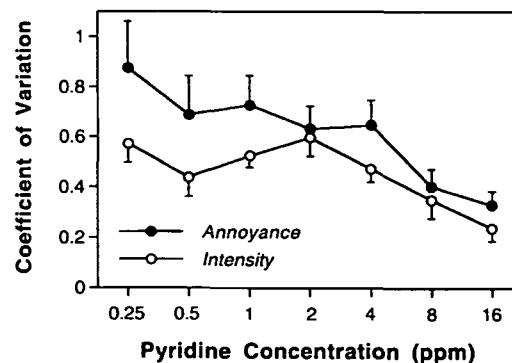


Figure 1 Mean (± SEM) intraindividual coefficients of variation (SD/mean) for odor annoyance and odor intensity as a function of pyridine concentration.

Table 1 Exponents (*n*) and goodnesses-of-fit (Pearson correlation coefficients; *r*) for psychophysical power functions and for odor annoyance as a function of odor intensity (intermodal power functions)

Subject	Psychophysical power function						Intermodal power function	
	Line length		Odor annoyance		Odor intensity		<i>n</i>	<i>r</i>
	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>		
A	0.94	0.998	0.64	0.905	0.50	0.888	1.25	0.988
B	0.98	0.997	0.61	0.931	0.35	0.932	1.54	0.876
C	1.00	0.998	0.21	0.989	0.29	0.944	0.68	0.967
D	0.88	0.998	0.35	0.846	0.30	0.775	0.98	0.903
E	0.93	0.999	0.51	0.937	0.45	0.883	0.99	0.935
F	0.72	0.977	0.48	0.917	0.56	0.935	0.85	0.974
G	0.94	0.997	0.42	0.956	0.43	0.928	0.94	0.990
H	1.14	0.994	0.15	0.878	0.18	0.835	0.68	0.870
I	1.05	0.995	0.40	0.907	0.25	0.828	1.28	0.863
J	0.86	0.995	0.71	0.882	0.59	0.939	1.10	0.867
K	1.08	0.995	0.36	0.944	0.53	0.893	0.55	0.846
L	0.79	0.998	0.36	0.958	0.37	0.936	0.92	0.942
M	1.04	0.998	0.37	0.987	0.42	0.959	0.80	0.943
N	0.94	0.993	1.04	0.990	0.55	0.935	1.74	0.972
O	0.78	0.988	0.52	0.944	0.58	0.933	0.88	0.997
P	0.90	0.993	0.32	0.909	0.23	0.956	1.36	0.934
Mean	0.94	0.995	0.47	0.930	0.41	0.906	1.03	0.929
SD	0.11	0.005	0.21	0.042	0.13	0.053	0.33	0.051
CV	0.12	0.01	0.46	0.05	0.33	0.06	0.32	0.06

CV = coefficient of variation (SD/mean).

interaction between modality and concentration [$F(6,90) = 1.28$], but an overall effect of concentration [$F(1,6) = 10.61$, $P < 0.001$]. This finding of similar variability in estimates for annoyance and intensity for odors is comparable to that reported for community noise, which, in fact, showed a strong tendency for smaller intraindividual coefficients of variation for annoyance than for loudness (Berglund and Preis, 1997). The decrease in variability with increased pyridine concentration for odor intensity is in accordance with previous findings (Nordin, 1994).

Psychophysical and intermodal power functions

Exponents and goodnesses-of-fit for individual psychophysical power functions are given in Table 1. The large correlation coefficients imply that the functions for odor annoyance, odor intensity and line length can adequately be described as a power function in its simplest form:

$$\Psi = c\Phi^n \quad (1)$$

where Ψ represents the perceived magnitude, Φ the stimulus magnitude, n the exponent and c the multiplicative constant (Stevens, 1957). All 16 subjects met the criteria for participation based on magnitude estimations of line length (Table 1), whereas one subject (not included among the 16)

did not meet the criteria. The average individual exponent for odor intensity (0.41) is identical to that previously reported for pyridine (e.g. Berglund *et al.*, 1988).

The exponents of the psychophysical power functions for annoyance and intensity differ only marginally, as suggested by averaged exponents (Table 1) and by a paired *t*-test showing no significant difference [$t(15) = 1.37$]. This implies that the relationship between intensity and annoyance of pyridine can be explained by a power function with an exponent that approaches unity. Since annoyance as a function of intensity can be predicted from the ratio between the annoyance and intensity exponents (cf. Stevens, 1975), the present results are validated by exponents approaching unity for both individual and group intermodal power functions (Table 1). A simple regression analysis relating predicted individual intermodal exponents to empirically obtained individual intermodal exponents (cf. Table 1) generated a slope of 1.08 and an intercept of 0.02 ($r = 0.975$). It is important to point out that although found for pyridine, exponents that are similar for annoyance and intensity may not be the general case for compounds with odorous and annoying characteristics. It is further of interest to note that the interindividual variation, expressed as the coefficient of variation, in these intermodal exponents is no larger than for annoyance and intensity.

Table 2 Results from simple regression analyses of exponents (*n*) and Pearson correlation coefficients (*r*) for various psychophysical functions (*df* = 1,15)

	Odor annoyance		Odor intensity	
	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>
Line length	<i>r</i> = -0.39	<i>r</i> = 0.09	<i>r</i> = -0.48	<i>r</i> = -0.20
Odor annoyance	—	—	<i>r</i> = 0.75***	<i>r</i> = 0.68**

** = *P* < 0.01, *** = *P* < 0.001.

Whereas the interindividual coefficients of variation for the exponent do not differ significantly between annoyance and intensity [Table 1; *t*(15) = 0.57; paired *t*-test on absolute deviations from respective group mean], the goodnesses-of-fit for the individual power functions were found to be significantly better for annoyance than for intensity [*t*(15) = 2.44, *P* < 0.05].

Table 2 presents results from simple regression analyses of individual power-function exponents between odor annoyance, odor intensity and line length, showing a significant correlation between annoyance and intensity of odors with respect to both exponent sizes and goodnesses-of-fit. Interestingly, no such significant correlations were found between odor annoyance and line length, nor between odor intensity and line length. Concerning the exponent, this may imply that the intraindividual correspondency between exponents for annoyance and intensity can predominantly be referred to as having a sensory basis rather than the subject simply showing a scaling behavior (affecting the slope of the function) that is the same for the two modalities. Thus, a person who perceives a relatively large increase in odor intensity due to a certain increase in stimulus concentration will also perceive a relatively large increase in odor annoyance for the same increase in concentration. However, considerable caution should be taken concerning this interpretation which is based on the result that exponents for annoyance and intensity of odors are, in contrast, not found to correlate with the exponents for line length. Thus, this lack of correlation may well be explained by the limited range of individual exponents for line length (cf. Table 1).

Master-scale equation

The need for a Master-scale equation for odor annoyance with which to calibrate annoyance scales for contextual effects and for group or individual differences in expressing annoyance magnitude may well be met by the presently obtained psychophysical group power function for annoyance. When annoyance (Ψ) and stimulus concentration (Φ) are expressed logarithmically, the group function can be described linearly as $\Psi = 0.466\Phi + 0.155$ (*r* = 0.969).

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