Combined contribution of roughness and sharpness to the unpleasantness of modulated bandpass noise.

Reinhard Weber, Reef Eilers

Institut für Physik, Fakultät V, Universität Oldenburg, 26111 Oldenburg, Deutschland, Email: reinhard.weber@uni-oldenburg.de

Introduction

In the tradition of the Munich psychoacoustic school the relationship between a global psychoacoustic entity as sensory pleasantness and psychoacoustic sensations e.g. sharpness and roughness has been investigated using magnitude estimation [1, 2, 3]. The summary of the investigations in Fastl/Zwicker [4] reports an exponential decrease of the sensory pleasantness as a function of sharpness and roughness. For bandpass noises with varying spectral shapes Widmann [5] investigated the relationship between sharpness and psychoacoustic annoyance, using the loudness of the noises as an additional parameter. Above a certain sharpness he found the psychoacoustic annoyance linearly growing with increasing sharpness and reported an interaction between loudness and sharpness on psychoacoustic annoyance. For higher loudness values sharpness contributes more pronounced to the psychoacoustic annoyance. Widmann also detected a slight increase of the psychoacoustic annoyance for very low sharpness values.
With a comparable look at the problem the present investigation tests the influence of sharpness and roughness and possible interactions on *unpleasantness* using modulated bandpass noise. To vary sharpness the center frequency of the stimuli is shifted whereas the spectral shape remains unchanged. Different roughness is realized by different degrees of modulation and in a paired comparison test the unpleasantness is evaluated.

Experimental setting

Stimuli

The stimuli consist of bandpass noise, two octaves broad, with a duration of 3 seconds filtered from pink noise. To avoid clicks the noises are smoothly switched on and off by a 50 ms slope. The amplitude of the filtered bandpass noise is modulated by $(1 + m \cdot \cos 2\pi f_{mod} t)$ with $f_{mod} = 70\,Hz$ and the degree of modulation m. After filtering 8 bandpass noises with center frequencies ranging from 315 Hz to 1590 Hz in third octave intervals three amplitude-modulated versions are generated of each bandpass noise with $m = 0.2$, 0.6 and 1, equivalent to modulation depths of -4, -12 and -40 dB. So 24 stimuli have been synthezised using Matlab, see table 1 together with calculated sharpness and roughness.

Method and subjects

The evaluation of the unpleasantness is performed by a complete paired comparison test in judging the more unpleasant stimulus of a stimulus pair. 20 subjects - 8 females and 12 males - have taken part in the test. Each subject has been evaluating all 276 noise pairs subdivided in three sessions with 92 comparisons each.
The stimuli are presented diotically via headphones in a soundproof booth. For all stimuli the dBA-level has been equalized to a common value of 65 dBA (measured monaurally). The stimuli are stored on a workstation, and a lab-own software written by Ping Rong[1] is used to perform the paired comparison task. The recommendations of Ross [6] for an optimal order of stimulus pairs are implemented. The subjects have the possibility to repeat the stimulus presentation as often as they need to make their decision and they also can freely decide when to continue. The time durations for the unpleasantness judgements have been logged.

Table 1: Stimuli - Band pass noises with a bandwidth of 2 octaves. Abreviations: f_c - center frequency, S - sharpness, m - degree of modulation, R - roughness

sound	f_c [Hz]	S [acum]	m	R [asper]
1	315	0.51	0.2	0.86
2	315	0.51	0.6	1.10
3	315	0.51	1	1.20
4	400	0.60	0.2	1.09
5	400	0.60	0.6	1.30
6	400	0.60	1	1.53
7	500	0.69	0.2	1.30
8	500	0.69	0.6	1.63
9	500	0.69	1	2.00
10	630	0.84	0.2	1.51
11	630	0.84	0.6	2.02
12	630	0.84	1	2.54
13	800	1.08	0.2	1.80
14	800	1.08	0.6	2.50
15	800	1.08	1	3.09
16	1000	1.35	0.2	1.87
17	1000	1.35	0.6	2.70
18	1000	1.35	1	3.60
19	1260	1.76	0.2	1.90
20	1260	1.76	0.6	2.90
21	1260	1.76	1	3.90
22	1590	2.38	0.2	1.77
23	1590	2.38	0.6	2.85
24	1590	2.38	1	4.15

[1] member of our team

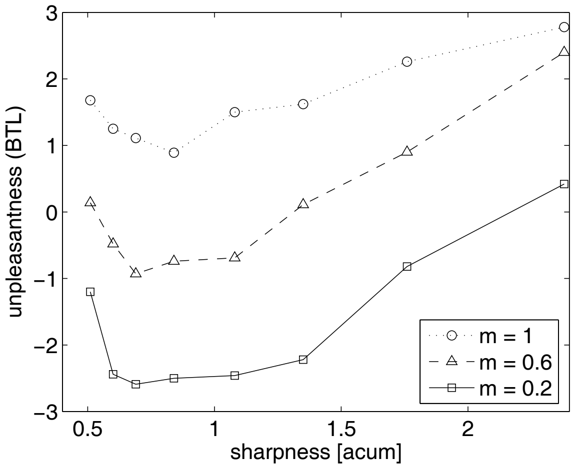

Figure 1: BTL-scaled unpleasantness scores of 24 amplitude-modulated bandpass stimuli (bandwidth: 2 octaves) with 8 center frequencies from 315 Hz to 1590 Hz successively separated by a third octave ratio. The corresponding sharpness in acum is given on the abszissa. The noises with equal degree of modulation are linked by lines. All three curves show a minimum of unpleasantness in the sharpness range from 0,6 to 1 acum, which corresponds to center frequencies from 400 to 800 Hz for these bandpass noises. The unpleasantness scores are not quite parallel for the three degrees of modulation, hinting to a certain interaction between roughness and sharpness for high sharpness data.

Results

For all subjects the calculation of the consistency coefficient $(1 - \frac{circular\ triads\ found}{maximally\ possible\ number\ of\ circular\ triads})$ yields sufficiently high (> 0.7) values between 0,73 and 0,97; hence all subjects can be included in the data analysis.
The BTL method [7] is used to provide scaled unpleasantness data and the accumulated set of preference matrices of all subjects serves as basic data set for the calculation. Three curves in Fig. 1 show the BTL-scaled unpleasantness data as a function of sharpness and all results refering to stimuli with the same degree of modulation ($m = 0.2/0.6/1.0$) are connected with solid lines. All three curves show a minimum of unpleasantness in the sharpness range from $0,6$ to $1\,acum$. This corresponds to a range of the center frequencies of the bandpass noises from 400 to 800 Hz. For higher ($1 < S$) and lower ($S < 0.7$) sharpness values the unpleasantness rises again. The relationship between unpleasantness and sharpness can be approximated rather well by a linear function in the region of higher sharpness values.
It far more difficult to characterize the influence of the calculated roughness on the unpleasantness evaluations, as may be suspected from the roughnness data given in table 1. Implicitely the effect of roughness can be studied by the effect of the degree of modulation on the unpleasantness. An increase of the degree of modulation from $m = 0.2$ to $m = 0.6$ nearly adds a constant offset to the lower unpleasantness curve (Fig. 1). In the region of higher sharpness the distance between the middle curve ($m = 0.6$) and the highest unpleasantness curve with $m = 1$ is no longer the same throughout the whole sharpness range investigated. It becomes considerably smaller for high sharpness values. As a higher degree of modulation is related to roughess by an exponential dependency these results indicate an interaction of roughness and sharpness on the unpleasantness.

Conclusions

In a paired comparison paradigm the unpleasantness of amplitude modulated bandpass noises has been judged by 20 subjects as a function of the center frequencies and of the degree of modulation. The level of the stimuli is held constant. The paired comparison results of all subjects are converted into interval scale values using the BTL-method. A representation of the unpleasantness over the calculated sharpness of the stimuli shows a minimum of the unpleasantness in the sharpness range from $0,6$ to $1\,acum$ corresponding to the range from 400 to 800 Hz for the center frequencies. A similar tendency can be guessed in the data of Widmann [5] on psychoacoustic annoyance but this finding is different to the course of the sensory pleasantness that monotonically decreases with increasing sharpness [4]. The judged unpleasantness shows an interaction between sharpness and roughness for higher sharpness values. For the purpose of sound design and sound engineering the observed minimum in the unpleasantness curve indicates that there might be an optimal frequency region for sound to be more pleasing.

References

[1] Terhardt, E., G. Stoll: Skalierung des Wohlklangs (der sensorischen Konsonanz) von 17 Umweltschallen (Scaling the sensory pleasantness of 17 environmental sounds and investigation of correlated hearing sensations). Acustica 48 (1981), 247-253

[2] Aures, W.: Der sensorische Wohlklang als Funktion psychoakustischer Empfindungsgrößen (Sensory pleasantness as a function of psychoacoustic sensations). Acustica 58 (1985), 282-290

[3] Aures, W.: Berechnungsverfahren für den sensorischen Wohlklang beliebiger Schallsignale (A procedure for calculating sensory pleasantness of various sounds). Acustica 59 (1985), 130-151

[4] Fastl, H. and Zwicker, E.: Psychoacoustics - Facts and Models. Springer-Verlag Berlin and Heidelberg, Berlin, 2005, 3rd edition

[5] Widmann, U.: Untersuchungen zur Schärfe und zur Lästigkeit von Rauschen unterschiedlicher Spektralverteilung (Sharpness and annoyance of noises with different spectral envelopes). In: Fortschritte der Akustik, DAGA '93 (1993), DPG-GmbH, Bad Honnef, 644-647

[6] Ross, R.T.: Optimal orders in the method of paired comparisons. Journal of Experimental Psychology, Vol. 25, (1939), 417-421

[7] David, H. A.: The Method of Paired Comparisons, 2nd ed. Oxford University Press, New York, 1988