The appropriateness of the psychoacoustic measures sharpness and roughness for the prediction of aesthetic impression caused by sound

(Die Tauglichkeit der psychoakustischen Maße Schärfe und Rauigkeit für die Vorhersage von Klangeindrücken)

Marcel Kloppenburg, Hans-Joachim Maempel*, Stefan Weinzierl**

* Technische Universität Berlin, Fachgebiet Kommunikationswissenschaft/Audiokommunikation, marcel.kloppenburg@gmx.de, hans-joachim.maempel@tu-berlin.de, stefan.weinzierl@tu-berlin.de

Abstract

As physical measures *sharpness* and *roughness* are used to describe sound quality as well as constructs like *euphony* or *annoyance*. It was investigated to what extent these measures can explain the aesthetic impression caused by sound. In a qualitative preliminary investigation, musical sounds of different sharpness and roughness were used to elicit subjects' relevant items for sound description. Based on those items, a semantic differential was constructed, by means of which 18 subjects were asked to rate 20 selected stimuli quantitatively. After correlation analysis of physical and psychological data it appears questionable whether sharpness and roughness are appropriate predictors for aesthetic impression caused by musical sound.

1. Introduction

In many domains, e.g. industrial sound design or corporate sound, acoustic stimuli are used to communicate certain values. In the first case e.g. a car door is acoustically designed as to stand for safety, quality and worth, while in the second case e.g. an acoustic logo might be supposed to communicate modernity, progress, or trust. Hearing abilities, listening conditions, sociocultural circumstances and individual value systems are very different; so many scientific disciplines are involved in the research of auditory perception and reception respectively. The question arises, to what extent perceptual phenomena are explainable by physical or psychoacoustic features of sounds. The psychoacoustic parameters *roughness* and *sharpness* are often used as predictors to describe timbre[1] or are parts of constructs like euphony [1] or annoyance [2]. However, their appropriateness for the prediction of more complex psychological effects such as aesthetic impressions or emotions has not been examined yet.

[1] To assess timbre, furthermore some investigations use verbal attributions [2][3][4][5][6].

2. Subject

In order to ensure reliability and comparability of data, *roughness* and *sharpness* are usually calculated from the waveform without adopting listening tests [7][8][9]. With regard to the use of these measures as predictors it was investigated to what extent calculated *sharpness* and *roughness* can statistically explain aesthetic impressions caused by musical sounds of identical chroma varying in octave and timbre.

3. Method

Firstly, musical sounds were recorded and analysed. Afterwards, verbal descriptions and attributions of the sounds were acquired during a qualitative listening session. Finally, a quantitative listening test was performed in order to collect numerical data, which were statistically analysed.

3.1 Stimuli

20 single musical tones of electronic and acoustic instruments (cello, saxophone, trombone) were recorded at the Music Hall of Berlin University of the Arts (UdK). The pitch was either A, a or a', whichever allowed comfortable intonation for all instruments. The recorded sounds were analysed using the software ArtemiS by Head Acoustics. It is possible to calculate *sharpness* either according to v. Bismarck [10] or according to Aures [11]. Because it considers the influence of loudness, Aures' method was used. *Roughness* was calculated according to [8]. The resulting values are shown in Chart 1. The variation of instrumental sounds form the independent variable in the quantiative listening test.

sound	roughness [asper]	sharpness [acum]
1	0,0443	2,150
2	1,420	2,935
3	1,575	1,070
4	0,297	0,880
5	0,441	1,240
6	2,425	1,115
7	0,327	0,570
8	0,098	0,854
9	1,610	0,833
10	1,695	1,775
11	0,123	0,704
12	0,156	2,490
13	1,920	0,953
14	0,173	1,660
15	0,111	1,590
16	0,252	1,765
17	1,295	1,685
18	1,050	0,888
19	0,259	2,830
20	0,234	3,160

Chart 1: Calculated values of roughness and sharpness

3.2 Verbal attributes

In order to obtain a variety of valid attributes describing the musical sounds aesthetically, emotionally or associatively, six subjects were asked to state their connotations with the stimuli presented by headphone (Stax SR-202). The statements were recorded on tape, transliterated and grouped with regard to similarity. From this material antonym paired attributes were derived and completed by attributes used in [12] and [13].

3.3 Semantic differential

Based on the collection of attributes a semantic differential was constructed, which consists of twenty bipolar seven-step rating scales: *pleasant (angenehm) – unpleasant (unangenehm), cold (kalt) – warm (warm), dangerous (gefährlich) – safe (ungefährlich), weak (schwach) – grand (erhaben), exciting (aufregend) – soothing (beruhigend), firm (hart) – smooth (weich), tense (angespannt) – calm (gelassen), melancholic (melancholisch) – cheerful (fröhlich), annoying (nervig) – not annoying (nicht nervig), brisk (lebhaft) – easy (ruhig), negative (negativ) – positive (positiv), touchy (zickig) – not touchy (nicht zickig), aggressive (aggressiv) – gentle (sanft), moving (bewegend) – not moving (nicht bewegend), shrill (schrill) – dull (dumpf), sharp (spitz) – rotund (rund), menacing (bedrohlich) – harmless (harmlos), unexpressive (ausdruckslos) – expressive (ausdrucksstark), snug (geborgen) – not snug (nicht geborgen), synthesised (synthetisch) – natural (natürlich)*. The scales form the dependent variables in the following quantitative listening test.

3.4 Listening test

The 20 musical sounds varying in timbre and *roughness/sharpness* respectively were used as stimuli in the quantitative listening test. They were arranged in three accidentally varied sequences and played to 18 subjects (non-expert listeners, age 23-62 years, 4 female / 14 male) individually by headphone (Stax SR-202), who were asked to rate them by means of a questionnaire containing the semantic differential.

4. Results

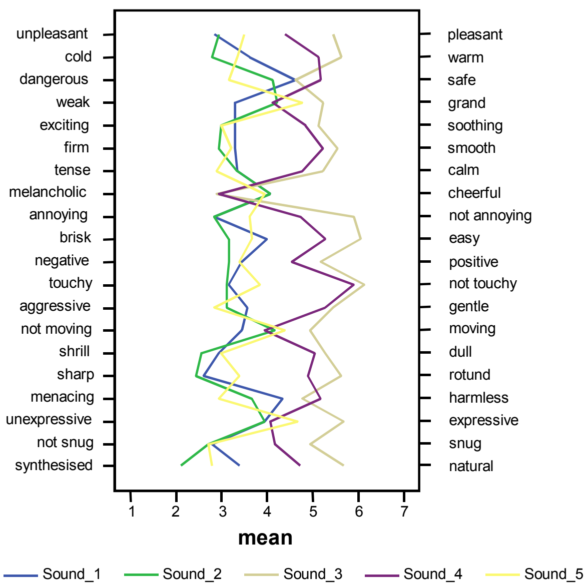

Fig. 1: Means of rated sounds 1-5

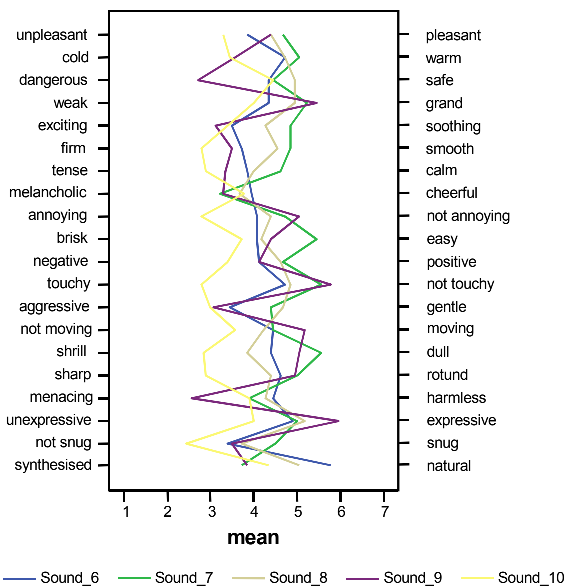

Fig. 2: Means of rated sounds 6-10

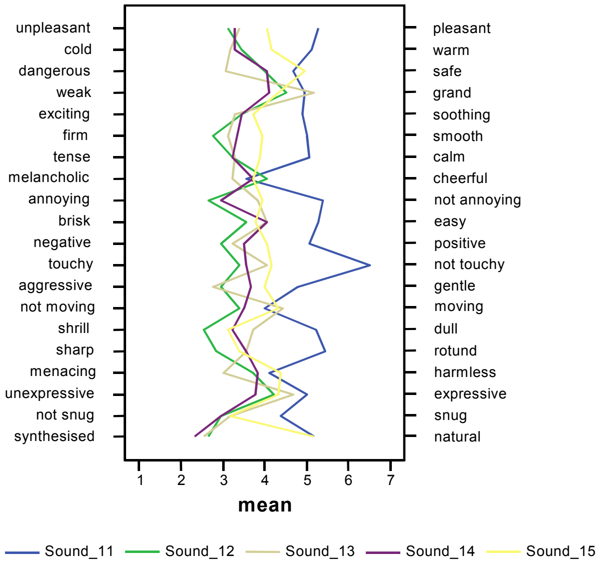

Fig. 3: Means of rated sounds 11-15

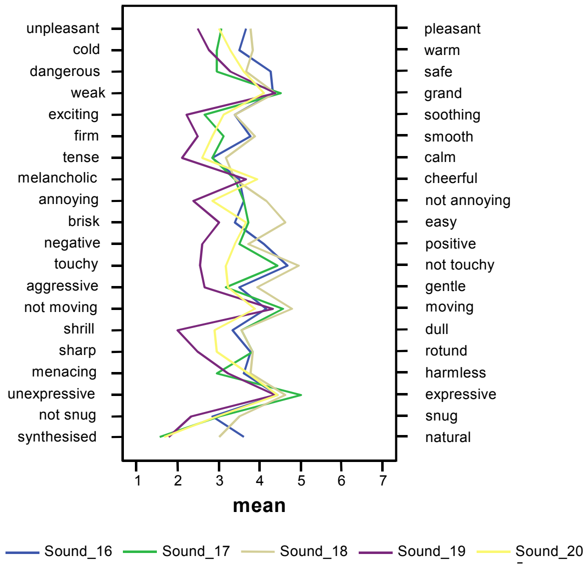

Fig. 4: Means of rated sounds 16-20

For each stimulus frequency distribution of subjects' ratings and common descriptive measures were computed. The resulting mean values are shown as profiles in Fig. 1-4.

5. Statistical analyses

5.1 Reliability

As a measure for the internal consistency of the data the Cronbach's α coefficient was calculated. It is 0.937 and indicates a high reliability of the ratings. However, the reliability tends to be overestimated, because the value of α rises with the number of variables, which is 400 in the present case (20 attributes, 20 stimuli, repeated measures).

5.2 Correlations

With respect to the small number of stimuli a nonparametric correlation analysis according to Spearman between the calculated parameters *roughness*/*sharpness* and the stimulus mean values of psychological parameters was computed. The results are listed in Chart 2. Among the dependent variables, there is just one (*moving*) correlating significantly with *roughness*, whereas 18 of them show significant or highly significant correlations with *sharpness*.

5.3 Dimensionality

In search of a structure of meaning the ratings are based on a principal component analysis (PCA) was performed. Thereby all ratings of the subjects were taken into account (stringing out method). According to the Kaiser-Guttman criterion [15][16] and the illustration of eigenvalues (scree plot, Fig. 5) three factors were extracted. Chart 3 shows the matrix of factor loadings (varimax-rotated solution). Factor loadings indicate bivariate correlations between components and variables [14], thus providing information about intercorrelations of the variables as well as about the meanings of the components.

variable (pos. scale pole)	**roughness**		**sharpness**	
	corr. coefficient spearman's rho	significance p (2-tailed)	corr. coefficient spearman's rho	significance p (2-tailed)
pleasant	,081	,733	-,875**	,000
warm	-,169	,477	-,696**	,001
safe	-,430	,058	-,274	,243
grand	,265	,260	-,639**	,002
soothing	-,183	,440	-,616**	,004
smooth	-,140	,556	-,770**	,000
calm	-,667	,743	-,667**	,001
cheerful	-,313	,178	,696**	,001
not annoying	,156	,510	-,891**	,000
easy	,098	,681	-,869**	,000
positive	-,061	,798	-,763**	,000
not touchy	,083	,729	-,863**	,000
gentle	-,350	,130	-,525*	,018
moving	,602*	,005	-,493*	,027
dull	,205	,385	-,889**	,000
rotund	,186	,433	-,851**	,000
harmless	-,254	,279	-,229	,331
expressive	,282	,229	-,655**	,002
snug	,024	,920	-,810**	,000
natural	,020	,932	-,592**	,006

Chart 2: Nonparametric correlations between roughness/sharpness and dependent variables

Relevant loadings are highlighted (Chart 3). Because of the large number of cases, the solution is to be interpreted non-restrictively. As shown in Chart 4, the components explain about two-thirds of the total variance and can be described as follwing:

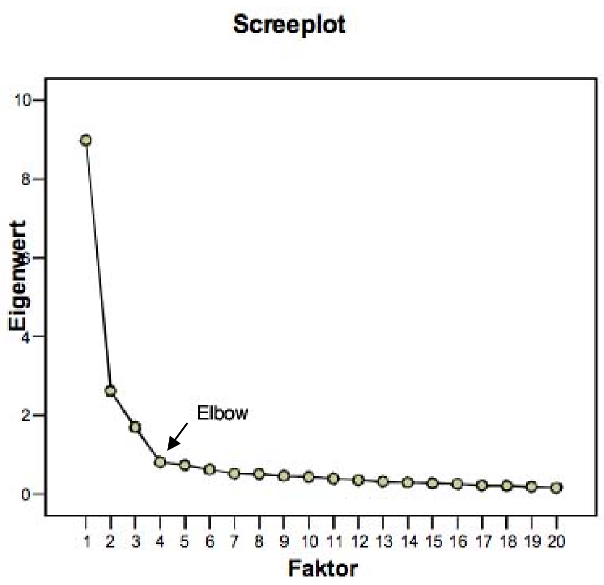

Fig. 5: Eigenvalues of components

variable (pos. scale pole)	component		
	1	2	3
pleasant	,708	,302	,391
warm	,686	,279	,173
safe	,826	-,132	-,221
grand	-,061	,179	,728
soothing	,687	,355	-,088
smooth	,674	,500	,132
calm	,750	,282	,049
cheerful	,169	-,738	,099
not annoying	,572	,462	,460
easy	,378	,706	-,078
positive	,723	,120	,385
not touchy	,444	,568	,425
gentle	,758	,386	-,018
moving	,087	-,067	,744
dull	,370	,703	,252
rotund	,402	,691	,282
harmless	,799	-,002	-,311
expressive	,033	,021	,845
snug	,692	,204	,317
natural	,648	,099	,330

Chart 3: Factor loadings (varimax-rotated solution)

component	% of variance	cumulative %	attributes
1	33,924	33,924	pleasant, warm, safe, soothing, smooth, calm, not annoying, positive, gentle, harmless, snug, natural
2	17,217	51,141	cheerful, easy, not touchy, dull, rotund
3	15,319	66,460	grand, moving, expressive

Chart 4: Factor loadings (varimax-rotated solution)

- The first component is dominated by positive connotations, particularly by *safe*, *harmless*, *gentle* and *calm*. All attributes associated with this component are rather consistant in their denotation. Summarising, component 1 can be described as 'comfort'.
- On the second component evaluative and emotional variables show high loadings. A good representation of the respective attributes can be found in the term 'melancholy'.
- The third component includes dominance-connotated attributes such as *expressive*, *moving*, *grand* and can recapitulated with 'strength of character'.

The three components obviously match the EPA-structure [17] largely, in which evaluation is represented by component 1, potency by component 3 and (negative) activity by component 2.

6. Discussion

The physical measure *sharpness* shows remarkably high correlations with 18 of the 20 rated attributes, which cover fundamental aesthetic dimensions ('semantic space') [17], while *roughness* just correlates with *moving*, an activity scale. Hence, although the calculated values of *roughness* showed a similar range as the *sharpness* values, *roughness* is obviously only a marginal factor regarding aesthetic impression in the realm of musical sounds.

7. References

[1] Aures, W. (1985a). "Der sensorische Wohlklang als Funktion psychoakustischer Empfindungsgrößen". In: *Acustica*, Bd. 58, S. 282-290. Hirzel Verlag, Stuttgart, p. 282.

[2] Bismarck, G. von (1974a). "Timbre of Steady Sounds: A Factorial Investigation of its Verbal Attributes". In: *Acustica*, Bd. 30, S. 146-159. Hirzel Verlag, Stuttgart, p. 152.

[3] Darke, G. (2005). "Assessment of Timbre Using Verbal Attributes". In: *Proceedings of the Conference on Interdisciplinary Musicology* (CIM05). Montréal. p. 1-12.

[4] Movarec, O. & Stepanek, J. (2003). "Verbal description of musical sound timbre in czech language". In: *Proceedings of the Stockholm Music Acoustics Conference.* Stockholm. p. 643-645.

[5] Movarec, O. & Stepanek, J. (2005). "Verbal descriptions of musical sound timbre and musician's opinion of their usage". In: *Proceedings of 31. DAGA.* München. p. 233-234.

[6] Stepanek, J. & Moravec, O. (2005). "Verbal description of musical sound timbre in Czech language and ist relation to musicians profession and performance quality". In: *Proceedings of the conference on Interdisciplinary Musicology* (CIM05), Montréal.

[7] Aures, W. (1985b). "Ein Berechnungsverfahren der Rauhigkeit". In: *Acustica*, Bd. 58, S. 268-281. Hirzel Verlag, Stuttgart, p. 277.

[8] Genuit et al. (1997). "Entwicklung einer Messtechnik zur physiologischen Bewertung von Lärmwirkungen unter Berücksichtigung der psychoakustischen Eigenschaften des menschlichen Gehörs". In: Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, Dortmund/Berlin, p. 41.

[9] Zwicker, E. & Fastl, H. (1999). *Psychoacoustics – Facts and Models.* 2. Ausgabe. Springer Verlag, Berlin, p. 239.

[10] Bismarck, G. v. (1974b). "Sharpness as an attribute of the timbre of steady sounds": In: *Acustica*, Bd. 30, S. 159-172. Hirzel Verlag, Stuttgart, p. 170.

[11] Aures, W. (1984). *Berechnungsverfahren für den Wohlklang beliebiger Schallsignale, ein Beitrag zur gehörbezogenen Schallanalyse.* Diss., München, Techn. Univ. p. 16.

[12] Bismarck, G. von (1974a). "Timbre of Steady Sounds: A Factorial Investigation of its Verbal Attributes". In: *Acustica*, Bd. 30, S. 146-159. Hirzel Verlag, Stuttgart.

[13] Västfjäll, D., Kleiner, M. (2002). "Emotion in Product Sound Design". In: Proceedings of Journées Design Sonore. Paris.

[14] Bortz, J. (1977). *Lehrbuch der Statistik für Sozialwissenschaftler.* Springer Verlag, Berlin, p. 627.

[15] Backhaus, K., Erichson, B., Plinke, W., Weiber, R. (2006). *Multivariate Analysemethoden.* 11. Aufl. Springer Verlag, Berlin, p. 295.

[16] Bortz, J. (1999). *Statistik für Sozialwissenschaftler.* Springer Verlag, Berlin, p. 528.

[17] Osgood, C., Suci, G., Tannenbaum, P. (1967). *The Measurement of Meaning.* University of Illinois Press, Urbana, p. 325.

[18] Terhardt, E. (1988). "Psychophysikalische Grundlagen der Beurteilung musikalischer Klänge". In: Meyer, J. (Hrsg.) *Qualitätsaspekte bei Musikinstrumenten.* Moeck Verlag, Celle, p. 20.