inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 0.0

SOUND QUALITY OF ELECTRIC RAZORS - EFFECTS OF LOUDNESS

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Keywords:
SOUND QUALITY, ELECTRIC RAZORS, LOUDNESS, APPLIED PSYCHOACOUSTICS

ABSTRACT
The sound quality of nine different electric razors, assessed in psychoacoustic experiments by a ranking procedure, was highly correlated to their percentile loudness N_5, i.e. the softest product was ranked best and the loudest product worst. This result stresses again that loudness is a dominant factor in sound quality evaluation. In several labs, original sounds of different products are manipulated to produce the same loudness in order to stress other aspects like sharpness or roughness. Therefore, the razor sounds were edited to produce the same percentile loudness N_5. Since larger level variations often lead to quite "unnatural" sounds, these manipulations had dramatic effects on the ranking: The product ranked best at its original level was ranked worst after a level increase by 11 dB (loudness increase by a factor of 2.27), and the product first ranked worst improved by two ranks with a level decrease of 5.5 dB (loudness decrease to 0.74). The variations in ranking are significantly related to the loudness variations. Therefore it is recommended to use in psychoacoustic experiments on sound quality as much as feasible original sound levels.

1 - INTRODUCTION

Evaluations of sound quality depend both on acoustic and non-acoustic factors (e.g. Blauert, 1996). With respect to acoustic factors, the perceived loudness plays a dominant role (Brennecke und Remmers 1983, Zwicker 1991, Widmann 1998, Fastl 1998, Kuwano et al. 1999). In addition, other hearing sensations like sharpness, fluctuation strength, or roughness can play an important role (Kuwano et al. 1997, Zwicker and Fastl 1999, Patsouras et al. 2000). In order to stress these cues, in some laboratories sounds produced by different products are reproduced at the same loudness. Also some labs try to predict the acceptance of future products by just reducing the level of current products.

In this paper, for the example of the sounds produced by different electric razors, the effects of loudness on sound quality rating were assessed in a pilot study. In particular, the prediction of sound quality by physical loudness measurements according to DIN 45 631 is challenged, and the effects of level variations and loudness variations on the ranking of product sound quality is assessed.

2 - EXPERIMENTS

Six male subjects with normal hearing ability and an age between 23 and 34 years (median 27 years) participated in the experiments. Sounds were presented idiotically by electrodynamic headphones (Beyer DT 48) with free field equalizer (Zwicker and Fastl, 1999, p.7) in a sound proof booth. Sounds of different types of electric razors were recorded in a distance of 30 cm in an anechoic chamber with no shaving operation to simulate to some extent the choice of an electric razor in a shop. From the original DAT-recordings, segments of 5 seconds were edited and stored on disc for random access. The task of the subjects was as follows: After reading an instruction in which they were informed that they had to rate the sound quality of electric razor sounds, they had to rank the products according to their sound quality. To the product with the best sound quality, they had to assign the rank 1, to the product with the worst sound quality the rank 9, and so forth. Subjects had random access to all nine electric razor sounds and could listen to them as often as they liked, and in any sequence and duration they liked. Their final

ranking was entered in a questionnaire, where they also gave reasons, why they ranked a specific product best or worst.
In a separate session on another day the subjects had to rank the same electric razor sounds, which however were edited to produce the same percentile loudness N_5. Of course, the subjects were not informed about the manipulation of the sounds, but were instructed just to rank another set of razor sounds. In figure 1, the loudness-time functions of the razor sounds are displayed. Original electric razor sounds are denoted A through I, sounds manipulated to produce the same percentile loudness N_5, a through i.

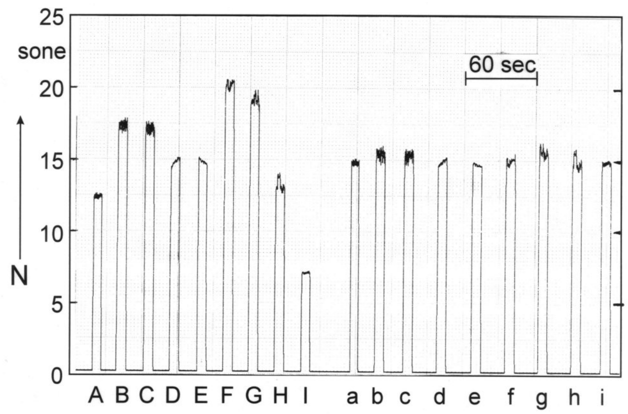

Figure 1: Loudness-time functions of sounds from electric razors; original sounds are denoted A through I, sounds edited to produce the same loudness N_5, a through i.

The loudness-time functions displayed in figure 1 clearly reveal that there are large differences in the loudness of the different products. For example, sound F is more than a factor of 3 louder than sound I. The right part of figure 1 illustrates that the goal to produce for all sounds of electric razors the same percentile loudness N_5 was achieved with deviations of only few percent.

3 - RESULTS AND DISCUSSION

Figure 2 shows the histograms of the ranking of sound quality for the nine original sounds from electric razors A through I. There is very good agreement in the ranking of the different subjects. For example, all subjects rank the razor sound I best (rank 1), and the razor sound A second (rank 2). On the other hand, razor sound F is ranked worst (dominance of rank 9). Among the reasons given for ranking sound I best are "soft", "pleasant", "well balanced", and for ranking sound F worst "loud", "annoying", "fluctuating".

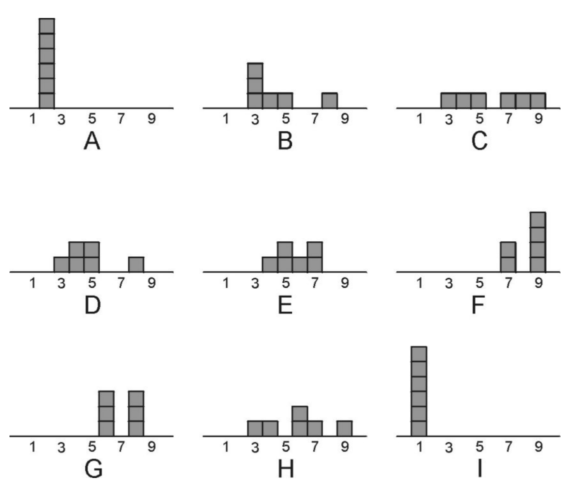

Figure 2: Ranking of the sound quality of the nine original electric razor sounds A through I; rank 1 corresponds to the best sound quality, rank 9 to the worst sound quality.

A comparison of the histograms displayed in figure 2 with the loudness-time functions given in figure 1 reveals a strong correlation of the ranking of sound quality to the loudness of the electric razor sounds.

For example, sound I with the lowest loudness gets the best ranking, sound A with the second lowest loudness value the second best ranking, and sound F with the largest loudness the worst sound quality ranking.

	A	B	C	D	E	F	G	H	I
N_5/sone	12.03	16.96	16.97	14.70	14.75	20.62	19.03	13.84	6.48
average ranking	2.00	4.33	6.00	4.83	5.66	8.33	7.00	5.83	1.00
ΔL/dB	2.5	-2.0	-2.5	-0.5	0	-5.5	-3.5	1.5	11
	a	b	c	d	e	f	g	h	i
N_5/sone	14.70	14.98	15.09	14.90	14.75	15.20	15.39	15.62	14.70
average ranking	5.00	1.50	3.16	4.50	5.66	6.16	6.33	5.50	7.16

Table 1: Percentile loudness N_5, average ranking and level corrections ΔL of the electric razor sounds investigated.

Table 1 enables a detailed comparison of the percentile values N_5 and the average ranking for the different products. When calculating Spearman's rank correlation coefficient (Sachs 1969) between percentile loudness N_5 and sound quality ranking of the original electric razor sounds, we get a value r_s=0.850 which is significant on the 5% level. This result again stresses the well known fact that sound quality of products is strongly related to their loudness (e.g. Fastl 1997).
Figure 3 shows the histograms of the ranking for the electric razor sounds when they are presented at same percentile loudness N_5.

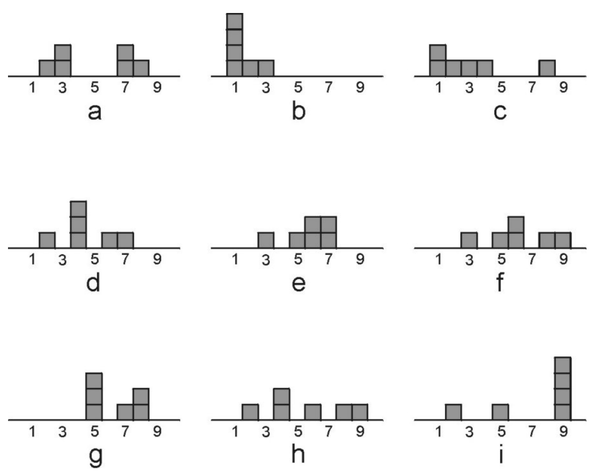

Figure 3: Same as figure 2, but for electric razor sounds presented at <u>same</u> percentile loudness N_5.

A comparison of the data displayed in figure 2 and figure 3 reveals that the histograms are more scattered in the latter case. This can be taken as an indication that for sounds of same loudness other aspects like sharpness, fluctuation strength, or roughness come into play, which sometimes are evaluated differently by different groups of subjects.
For example for sound a, we find some type of a bimodal distribution, and for many sounds (e.g. c, h, i), responses are rather scattered. Reasons given for top ranks include "no roughness", "decent", "pleasant", "no annoyance", whereas products ranked low sound "fluctuating", "metallic", "rattling" and "annoying".
Of particular interest is the fact that the product ranked best at its original loudness (I) is now ranked worst (i). A more detailed comparison of the shift in average ranking produced by the variations of the original loudness of the products can be seen in table 1. For example, product A looses three ranks (from 2.00 to 5.00) presumably because its loudness was increased. On the other hand, the sound of product F can gain about two ranks with a decrease in loudness.

Since the modified sounds of the electric razors a through i all produce essentially the same loudness N_5, no correlations of the rankings to the loudness are expected. This expectation is confirmed by a statistical analysis which gives a rank correlation coefficient r_s=-0.05 which is not significant.
The results displayed in figure 4 enable a discussion of the effects of level variations or loudness variations on the ranking of sound quality. The differences in ranking are plotted as a function of the level difference or the loudness ratio. According to the concept of psychoacoustic annoyance (Widmann 1998, Zwicker and Fastl 1999) loudness is one of the main constituents of sound quality rating. For example, if the level of sound I is increased by 11 dB, the loudness is increased by a factor of 2.27, and the sound quality looses more than six ranks. On the other hand, when the level of product F is decreased by 5.5 dB, the loudness decreases to 0.74 and the sound quality gains more than two ranks. A correlation analysis between the loudness ratio and the difference in sound quality ranking shows correlation (r_s=0.808) on the 10%-level. This means that to some extent ranking differences in sound quality can be predicted from loudness ratios produced by the sound manipulations. However, the regression lines in figure 4 show that there are additional influences, and product sound quality of course depends on additional psychoacoustic magnitudes.

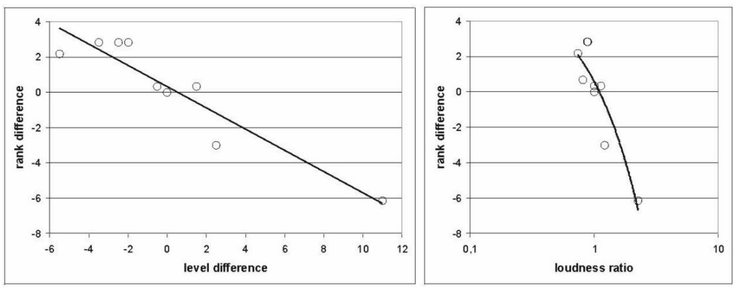

Figure 4: Differences in sound quality ranking as a function of level differences (left) or loudness ratios (right).

4 - SUMMARY

Results of a pilot study again confirmed that the acoustic aspects of product sound quality crucially depend on the loudness of the sound. Deviations from the original reproduction level and hence the original loudness of the product have to be performed with utmost care, since variations of only 2 dB can lead to significant differences in sound quality ranking. The original loudness of a product sound should be kept as much as possible at the original value and deviations of more than ±10% should be avoided. The predictive value of simple level variations with respect to estimates of sound quality should not be overestimated, since other aspects like tone color and temporal structure may have a crucial influence.

ACKNOWLEDGEMENTS

The author wishes to thank Dipl.-Ing. Thomas Filippou and Dipl.-Ing. Christine Patsouras for their support in realizing this study.

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