# A Cross-Cultural Study of the Factors of Sound Quality of Environmental Noise

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**Summary:** The sound quality of various environmental noises was judged using semantic differential in Japan, Germany, the U.S. and China. The sounds used were aircraft noise, train noise, road traffic noise, speech, music and construction noise. As the result of factor analysis, three factors were extracted in Japan and Germany. They were interpreted as "powerful", "pleasant" and "metallic" factors. In the U.S. and China, "powerful" and "metallic" factors were not differentiated. There seemed some difference in connotative meanings of the terms "loud", "noisy" and "annoying" among four countries. LAeq showed good correlation with loudness in the four countries. On the other hand, LAeq did not always show good correlation with annoyance when various sound sources were combined. Annoyance seems to be affected by non-acoustic factors. When each sound source is examined independently, LAeq shows good correlation with annoyance judgment. This suggests that LAeq can be used for the evaluation of the annoyance of each sound source and that the permissible level of noise should be considered for each sound source taking the non-acoustic factors into consideration. The concept of noisiness seems unclear and different in each country. This may make confusion in the international discussion. It would be better to use the term "noise quality" instead of "noisiness" in order to express the unpleasant impression.

## INTRODUCTION

In our former cross-cultural study of noise problems, the connotative meaning of the concept of "loudness", "noisiness" and "annoyance" were examined by using semantic differential in five countries[1),2)]. All concepts except for loudness in Japan and China, were found to have negative images. Japanese and Chinese loudness were judged as neutral. In our former study, only the concepts of the terms were judged without presenting sounds. In the present study the recorded environmental sounds were presented to subjects and the usage of the terms were examined as well as the relation between physical measures and the subjective impressions. The experiment was conducted in Japan, north and south Germany, the U.S. and China.

## EXPERIMENT

**Stimuli:** 24 stimuli were used except for the experiment in Oldenburg where C4 was missed. They are listed in Table 1. The duration was about 10 sec.

Table 1 Sound sources

| abbreviation | sound source | $L_{Aeq}$ | abbreviation | sound source | $L_{Aeq}$ |
|---|---|---|---|---|---|
| A1 | aircraft noise | 81.8 | S1 | speech | 82.0 |
| A2 | aircraft noise | 71.8 | S2 | speech | 72.9 |
| A3 | aircraft noise | 64.8 | S3 | speech | 64.3 |
| A4 | aircraft noise | 54.1 | S4 | speech | 53.9 |
| T1 | train noise | 79.2 | M1 | music | 81.4 |
| T2 | train noise | 74.8 | M2 | music | 76.1 |
| T3 | train noise | 65.1 | M3 | music | 65.0 |
| T4 | train noise | 53.9 | M4 | music | 53.8 |
| R1 | road traffic noise | 77.9 | C1 | construction noise | 84.6 |
| R2 | road traffic noise | 70.7 | C2 | construction noise | 73.4 |
| R3 | road traffic noise | 57.6 | C3 | construction noise | 67.8 |
| R4 | road traffic noise | 47.1 | C4 | construction noise | 54.9 |

**Procedure:** The impression of the sounds were judged using semantic differential. Fourteen pairs of adjectives were used as shown in Table 2. The original adjective list was prepared in Japanese and translated into English and Chinese. English version was translated into German. These translations were conducted on the basis of our former studies and with the discussion among researchers. The experiment was conducted with the native language in each country except for the experiment in Munich, where English was used.

**Apparatus:** The stimuli were reproduced with a DAT recorder. They were presented to subjects in random order through an amplifier and loudspeakers. Headphones with a free-field equalizer were used in the experiment in Munich.

**Subjects:** The numbers of subjects were 171 in Japan, 119 in U.S.A., 250 in China, 18 in Munich and 57 in Oldenburg. Most of them were university students and young researchers.

## RESULTS

**Factor analysis:** Factor analysis was conducted and the results are shown in Table 2. Three factors were extracted in Japan and Germany. They were interpreted as "powerful", "pleasant" and "metallic" factors. In the U.S. and China, only two factors were extracted and "powerful" and "metallic" factors were not differentiated.

In all the countries, "loud", "strong" and "powerful" belong to the "powerful" factor. On the other hand, "noisy" and "annoying" are not simple. In Japan both "noisy" and "annoying" have high loadings with "powerful" factor and "pleasant" factor. In Germany (both in Munich and Oldenburg) "annoying" shows high negative loadings with "pleasant" factor while "noisy" shows high loadings with both "powerful" factor and "pleasant" factor. The results in the U.S. and China shows the same tendency as in Germany.

**Concept of "loud", "noisy" and "annoying":** The terms "loud", "noisy" and "annoying" are used for expressing the effect of noise. The definition of these terms has often been discussed and has not yet reached agreement though the loudness is defined in IEC terminology (801-29-03). The relation between these terms are examined on the basis of the data of the experiments.

Table 3 shows the coefficient of correlation between $L_{Aeq}$ and adjective scales "loud", "noisy" and "annoying" for all the sound sources together and those for each sound source. When all the sound sources are combined, $L_{Aeq}$ shows good correlation with loudness. On the other hand, coefficient of correlation between $L_{Aeq}$ and noisiness or annoyance is not always high. However, when each sound source is examined independently, $L_{Aeq}$ shows high correlation in most cases. Examples of the relation between $L_{Aeq}$ and loudness, noisiness and annoyance are shown in Figs.1-3.

Loudness level based on ISO 532B showed similar tendency as $L_{Aeq}$. Other physical measures such as sharpness and roughness did not show good correlation with subjective judgments.

## CONCLUSION

In order to discuss about noise problems, it would be important to make clear the connotative meaning of the terms used. From the results of the experiments conducted in five places in the four countries, it was suggested that loudness may be a suitable concept to be used in order to examine the relation between physical measures and subjective impressions. In this experiment, $L_{Aeq}$ showed good correlation with loudness as found in our former studies[3].

$L_{Aeq}$ did not always show good correlation with annoyance when various sound sources were combined. That is, even if the values of $L_{Aeq}$ are the same, annoyance may be different. Annoyance seems to be affected by non-acoustic factors such as subjective meaning of the sound sources. However, when each sound source is examined independently, $L_{Aeq}$ shows good correlation with annoyance judgment. This suggests that $L_{Aeq}$ can be used for the evaluation of the annoyance of each sound source and that the permissible level of noise should be considered for each sound source taking the non-acoustic factors into consideration.

Table 2 Result of factor analysis

| adjective | Japan | | | Germany (Munich) | | | Germany (Oldenburg) | | | U.S. | | China | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | I | II | III | I | II | III | I | II | I | II |
| loud - soft | -.188 | .836 | .150 | -.327 | .734 | .293 | -.318 | .799 | -.149 | -.792 | -.336 | -.183 | .806 |
| beautiful - ugly | .903 | -.158 | -.044 | .894 | -.180 | -.196 | .922 | -.182 | -.135 | .177 | .866 | .778 | -.147 |
| pure - impure | .870 | -.156 | .008 | .628 | -.050 | -.140 | .379 | .168 | -.635 | -.320 | .407 | .625 | .141 |
| hard - soft | -.545 | .330 | .466 | -.475 | .555 | .443 | -.558 | .672 | -.135 | -.748 | -.434 | -.264 | .763 |
| sharp - dull | .045 | .209 | .538 | -.123 | .284 | .698 | -.099 | .351 | -.632 | -.756 | -.080 | .064 | .518 |
| strong - weak | -.220 | .822 | .268 | -.168 | .857 | .194 | -.184 | .854 | -.216 | -.853 | -.153 | -.157 | .873 |
| deep - metallic | .669 | -.022 | -.398 | .156 | -.072 | -.604 | -0.27 | -.019 | .600 | .264 | .381 | .406 | .104 |
| annoying - not annoying | -.609 | .609 | .151 | -.681 | .309 | .123 | -.884 | .292 | .037 | -.319 | -.762 | -.741 | .332 |
| mild - gruff | .664 | -.485 | -.248 | .634 | -.492 | -.406 | -702 | -.498 | -.105 | .450 | .615 | .524 | -.517 |
| pleasant - unpleasant | .873 | -.301 | -.080 | .896 | -.227 | -.193 | -919 | -.223 | -.065 | .195 | .875 | .849 | -.212 |
| powerful - weak | -.125 | .775 | .214 | -.135 | .868 | .118 | -.151 | .853 | -.177 | -.775 | -.079 | .080 | .702 |
| pleasing - unpleasing | .872 | -.267 | -.057 | .919 | -.201 | .166 | .908 | -.134 | -.112 | .176 | .890 | .836 | -.181 |
| shrill - calm | -.422 | .329 | .496 | -.450 | .460 | .582 | -.701 | .467 | -.148 | -.606 | -.492 | -.156 | .710 |
| noisy - quiet | -.610 | .633 | .205 | -.651 | .490 | .376 | -.635 | .650 | -.049 | -.673 | -.538 | -.648 | .467 |

The concept of noisiness seems unclear and different in each country. This may make confusion in the international discussion. It would be better to use the term "noise quality" instead of "noisiness" in order to express the unpleasant impression.

## REFERENCES

1) S. Namba, S. Kuwano and A. Schick, J. Acoust. Soc. Jpn. (E), 7, 279-289 (1986). 2) S. Namba, et al., J. Sound Vib., 151, 471-478 (1991). 3) S. Namba and S. Kuwano, J. Acoust. Soc. Jpn. (E), 5, 135-148 (1984).

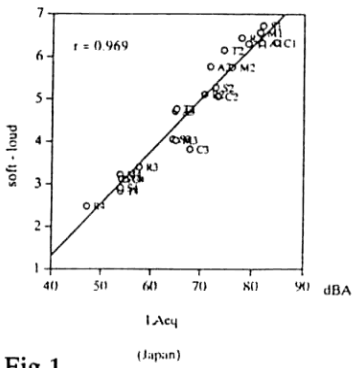


Fig.1

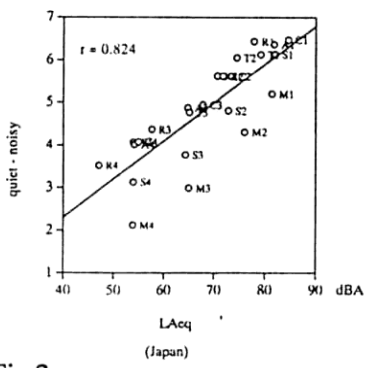


Fig.2

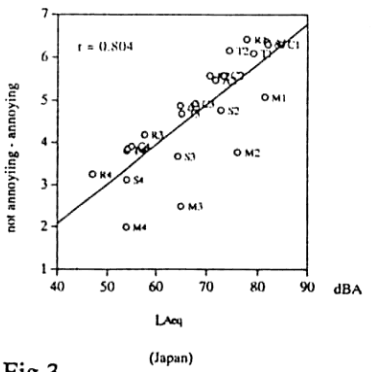


Fig.3

Table 3 Coefficient of correlation between LAeq and adjective scales

| | | Japan | Munich | Oldenburg | U.S. | China |
|---|---|---|---|---|---|---|
| All sound sources together | loud | .969 | .855 | .838 | .959 | .958 |
| | noisy | .824 | .571 | .679 | .881 | .634 |
| | annoying | .804 | .364 | .481 | .591 | .531 |
| aircraft noise | loud | .992 | .990 | .981 | .967 | .994 |
| | noisy | .998 | .970 | .970 | .994 | .997 |
| | annoying | .999 | .925 | .986 | .998 | .976 |
| train noise | loud | .987 | .899 | .856 | .962 | .959 |
| | noisy | .980 | .971 | .922 | .985 | .977 |
| | annoying | .975 | .904 | .882 | .996 | .966 |
| road traffic noise | loud | .991 | .984 | .979 | .982 | .983 |
| | noisy | .998 | .970 | .952 | .995 | .989 |
| | annoying | .999 | .977 | .964 | .978 | .977 |
| speech | loud | .996 | .979 | .932 | .998 | .996 |
| | noisy | .983 | .949 | .900 | .992 | .993 |
| | annoying | .972 | .967 | .845 | .957 | .927 |
| music | loud | .985 | .989 | .921 | .984 | .993 |
| | noisy | .989 | .970 | .887 | .978 | .865 |
| | annoying | .953 | .942 | .717 | .892 | .797 |
| construction noise | loud | .972 | .964 | - | .972 | .986 |
| | noisy | .996 | .943 | - | .993 | .990 |
| | annoying | .996 | .859 | - | .997 | .990 |