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Comparison of subjective impression of copy machine noise between Japanese, American and German participants

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Psychological evaluations of copy machine noise are in progress to lower acoustical noise and to avoid disturbing the office environment. Psychological experiments were made for Japanese, American and German participants to examine cultural differences in sensitivity to copy machine noise using the Semantic Differential. The experiments revealed that, just as with Japanese, Americans and Germans were mostly sensitive to "sound pressure levels." However, the second influential factor for Japanese participants was "roughness" but "sharpness" for Americans and Germans. Evaluation formulas for "pleasing" noise using physical values were decided for each country. This suggests that copy machine noise will be evaluated without psychological experiments. The information gathered will possibly be used to adapt copy machine noise to levels that are comfortable to users in different countries.

1 Introduction

As copy machines and laser printers become smaller, they can be placed closer to the people who use them. This means noise must be reduced so that the machines don't disturb the people around them. Copy machines have several sound sources, so when sources with good sound quality or a masking effect are reduced, total sound quality worsens. To reduce noise that bothers people, therefore, we need to do psychological evaluations of copy machine noise. Fastl et al made psychological evaluations for impact printer sounds. [1)] Takada et al did the same for laser printers. [2)] Copy machines have more functions and more sound sources than printers, so further studies for copy machines are required. We also know that sound impressions depend on cultural experience. For that reason, cross-cultural studies to improve the sound quality of copy machines are needed for application to the world market. Psychological evaluations using Semantic Differential were made for Japanese, American and German participants to gain the knowledge needed to adapt copy machine noise to levels that are comfortable to users across the globe.

2 Experiments

Fig.1 shows the recording system of copy machine sounds. Seventeen sounds were recorded in a semi-anechoic chamber according to the procedure described in ISO7779 at the bystander's position. These sounds were collected from seven copy machines and four laser printers. Some of the copy machines were used to collect sounds produced by successive one side copying and both side copying. Print speeds were from 12 to 55 prints per minute. Every sound was cut to six seconds for use as stimuli for the psycho-acoustical evaluation. This means that every stimulus had at least one cycle copy duration.

Fig.2 shows the psychological evaluation system. These sounds were played back in random order by DAT player for participants wearing electrodynamic headphones with freefield equalizer. Sounds were presented twice in different sequences and participants were asked to evaluate the impressions using seven categorized scales for 16 kinds of adjective pairs, obeying the Semantic Differential.

There were twenty Japanese participants (nine females and eleven males ranging in age from 21 to 46 years – average 26.4 years), 15 American participants (five females and ten males ranging in age from 31 to 59 years –average 45.1 years) and twenty German participants (all males ranging in age from 22 to 42 years – average 26.6 years).

The experiments were made at Osaka Univ. in Japan, Ricoh corp. in San Jose, California, USA, and Technical Univ. Munich, Germany.

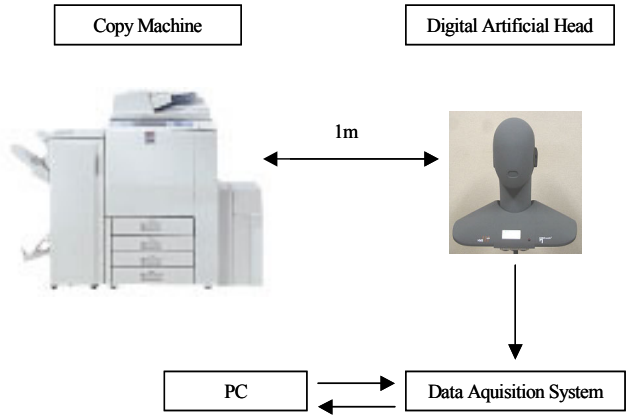

Fig.1 Recording system of copy machine sounds

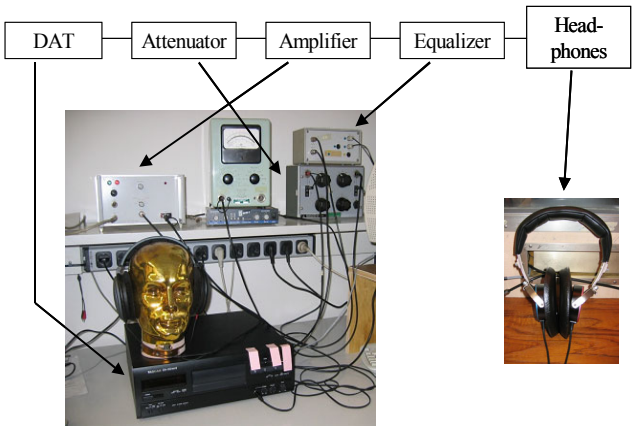

Fig.2 Psychological evaluation system

3 Results

Fig.3 shows the result of Japanese scores for stimulus No.5, 7, 17, which gave comparatively good impressions. Fig.4 and Fig.5 show the results of American and German scores with the same stimuli. Every figure shows that these stimuli gave fairly good impressions: smooth, stable, pleasant and gentle.

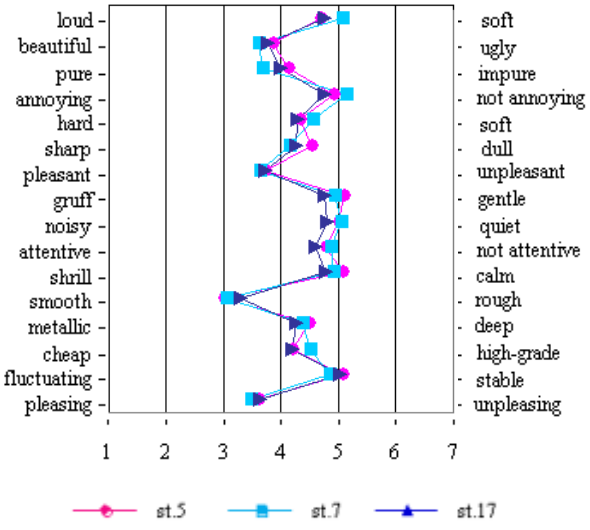

Fig.3 Profile of good impression (Japanese)

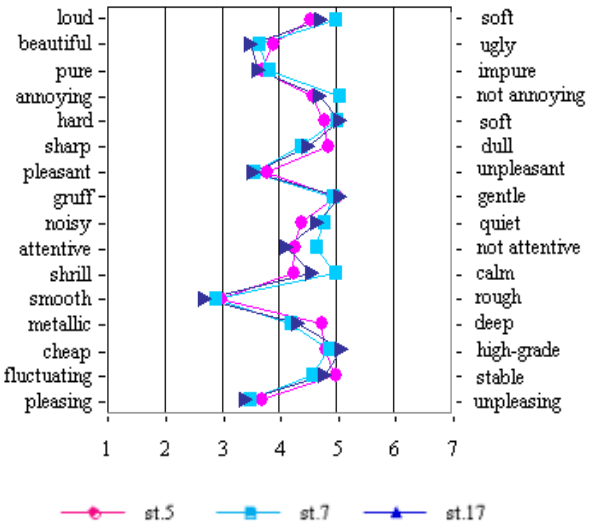

Fig.4 Profile of good impression (Americans)

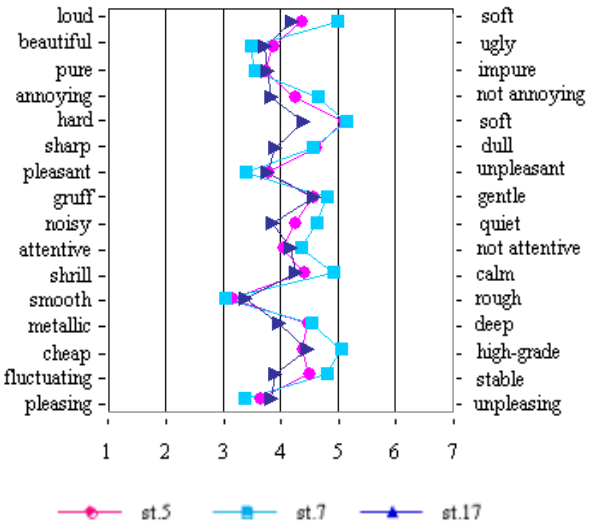

Fig.5 Profile of good impression (Germans)

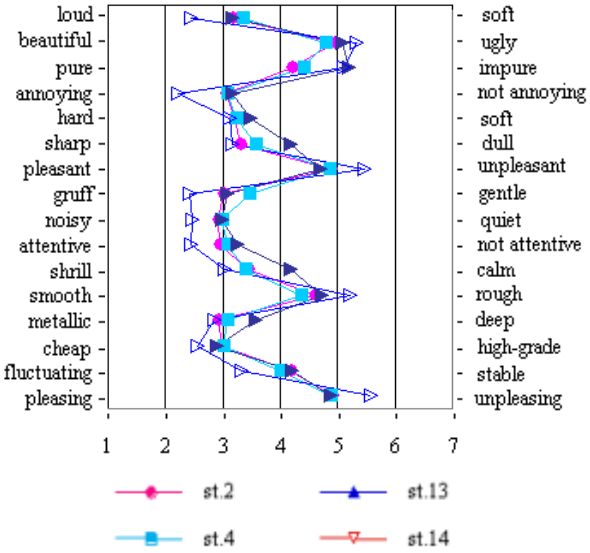

Fig.6 Profile of bad impression (Japanese)

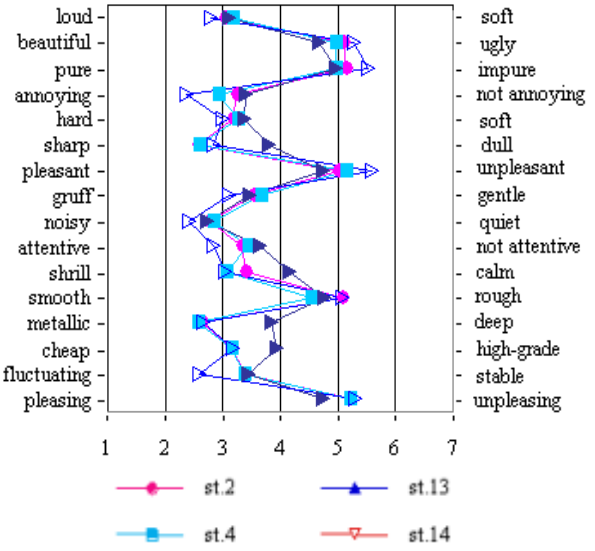

Fig.7 Profile of bad impression (Americans)

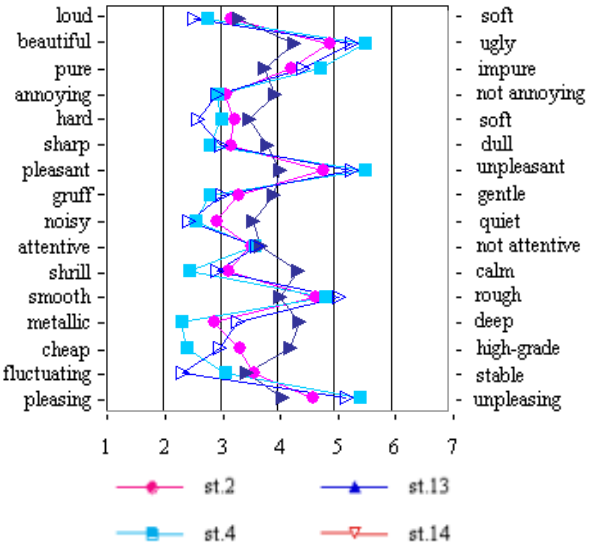

Fig.8 Profile of bad impression (Germans)

Fig.6 shows the result of Japanese scores for stimulus No.2, 4,13,14, which gave comparatively bad impressions. Fig.7 and Fig.8 show the results of American and German scores with the same stimuli. No. 14 stimuli gave rather bad impressions in every country. But No.13 stimuli did not have as bad impression on Germans as it did on Japanese. Comparing the physical values, revealed that No.13 stimulus was good at "sharpness" against No.2, 4, 14. So, "sharpness" may have a bad impression on Germans.

Table 1 lists the results of factor analysis. Three factors were extracted from the Japanese results. F1, the first factor, seemed to be a pleasant plus powerful factor. F2, the second factor, seemed to be a metallic factor. The third factor showed fluctuations. This suggests that participants feel pleasant when the sound is soft and not noticeable. In the American results, two factors were extracted. First factor F1 seemed to be a powerful and pleasant factor. F1 also had a slight metallic factor. This suggests that participants feel pleasant when the sound is soft and with fewer high frequency ingredients. Second factor F2 seemed to show fluctuations. In the results with Germans, three factors were extracted. First factor F1 seemed to be a powerful and metallic factor. Second factor F2 seemed to present pleasantness. Third factor F3 presented only attentiveness.

Then "pleasing" factor indicating an overall evaluation of sound was analyzed. The "pleasing" value was compared with physical values that were analyzed by sound quality evaluation software. Evaluated physical values were "sound pressure levels (L_{Aeq})," "loudness," "sharpness," "tonality," "impulsiveness," "fluctuation strength," and "roughness." Correlations between "pleasing" and physical values were analyzed. The correlations revealed that, just as with Japanese, Americans and Germans were mostly sensitive to "sound pressure levels." The second influential factor for Japanese participants was "roughness." For Americans and Germans, however, it was "sharpness." With these results, the formulas of "pleasing" were decided. The formulas of "pleasing" are presented as follows;

Japanese; Y ("pleasing") = f ("SPL", "roughness")
Americans; Y ("pleasing") = f ("SPL", "sharpness") (1)
Germans; Y ("pleasing") = f ("SPL", "sharpness")

Figures 9 to 11 show the relationships between psychological value "pleasing" and physical value "sound pressure levels (L_{Aeq})." They show good correlations, as the correlation efficient for Japanese is 0.889, and 0.894 and 0.718 for Americans and Germans. Figures 12 to 14 show the relationships between estimated "pleasing" and experimentally evaluated "pleasing" for each country. These estimated "pleasings" were calculated by formula (1). The figures show that the estimations correlate well with experimental values.

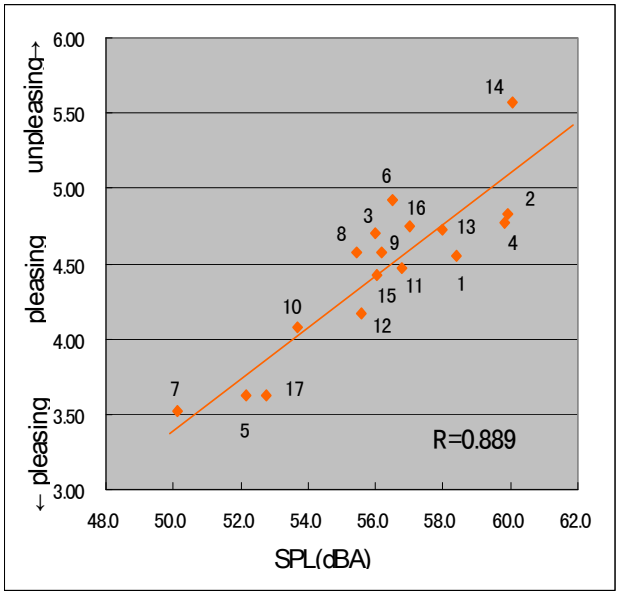

Fig.9 SPL vs. pleasing (Japanese)

Table 1 Results of factor analysis

	Japanese			Americans		Germans		
	F1	F2	F3	F1	F2	F1	F2	F3
loud - soft	0.7900	0.3145	-0.0114	0.7646	0.2649	0.6299	0.3477	0.1724
beautiful - ugly	-0.8023	-0.0877	-0.2925	-0.5496	-0.6301	-0.5722	-0.6494	-0.2100
pure - impure	-0.6489	0.2089	-0.4275	-0.1963	-0.7842	-0.0205	-0.7894	0.1527
annoying - not annoying	0.8189	0.3313	0.0895	0.8109	0.3662	0.3178	0.5171	0.4777
hard - soft	0.4743	0.5334	0.2824	0.5592	0.6019	0.8389	0.1881	0.0558
sharp - dull	0.0375	0.8690	-0.0246	0.5316	0.4633	0.6989	0.1202	0.1875
pleasant - unpleasant	-0.7987	-0.2284	-0.2668	-0.7299	-0.4970	-0.5537	-0.6863	-0.2034
gruff - gentle	0.7542	0.2646	0.2877	0.4192	0.7123	0.7469	0.4153	0.0804
noisy - quiet	0.7935	0.3593	0.1335	0.6960	0.4166	0.5957	0.5275	0.2451
attentive - not attentive	0.7862	0.3195	0.1626	0.7924	0.0218	0.0875	-0.0030	0.9076
shrill - calm	0.3306	0.6808	0.3553	0.7097	0.2995	0.6662	0.3975	0.1709
smooth - rough	-0.6156	-0.1766	-0.5488	-0.3720	-0.7855	-0.7726	-0.3054	0.0994
metallic - deep	0.4282	0.6747	0.0846	0.4310	0.4614	0.7641	0.1211	0.1681
cheap - high-grade	0.7850	0.2251	-0.0635	0.5211	0.5496	0.5250	0.6595	0.1859
fluctuating - stable	0.0685	0.1677	0.9006	0.0924	0.8349	0.6058	0.3585	0.1425
pleasing - unpleasing	-0.8351	-0.1929	-0.2209	-0.6976	-0.4820	-0.5572	-0.6434	-0.1136

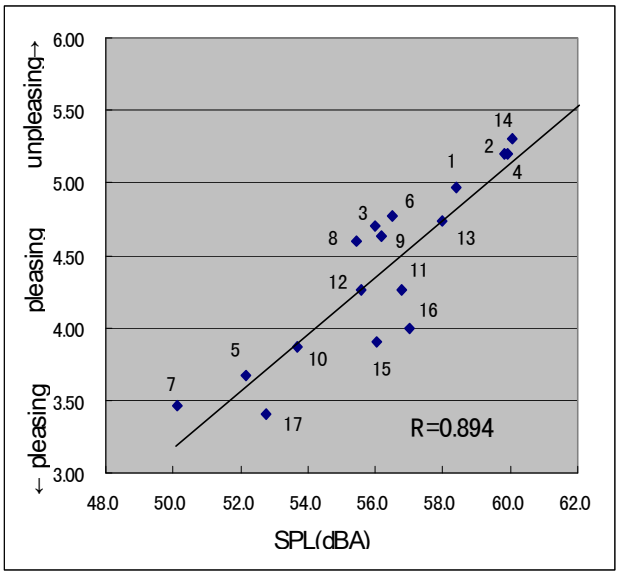

Fig.10 SPL vs. pleasing (Americans)

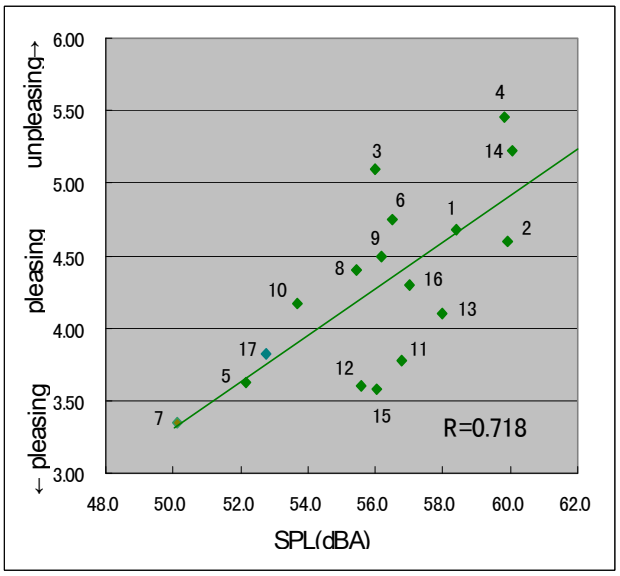

Fig.11 SPL vs. pleasing (Germans)

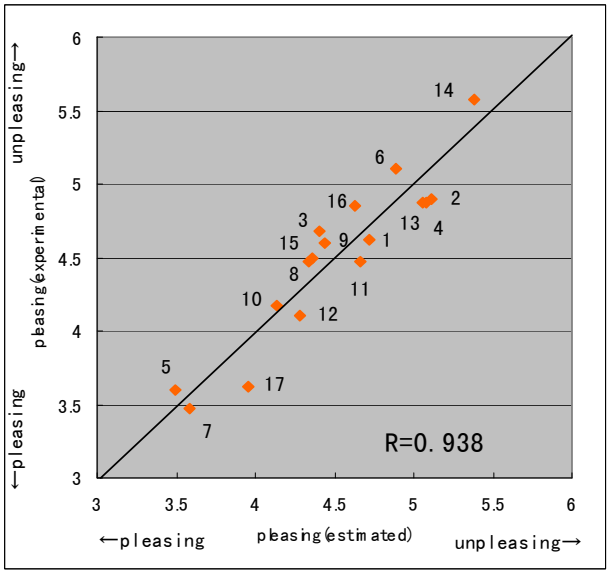

Fig.12 Pleasing values of Japanese

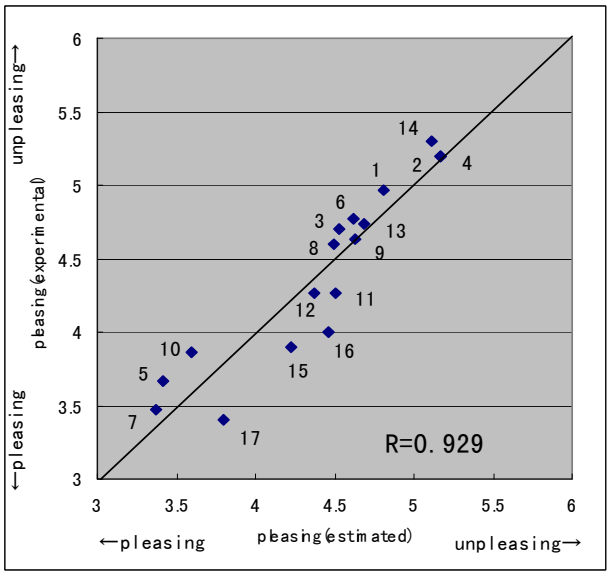

Fig.13 Pleasing values of Americans

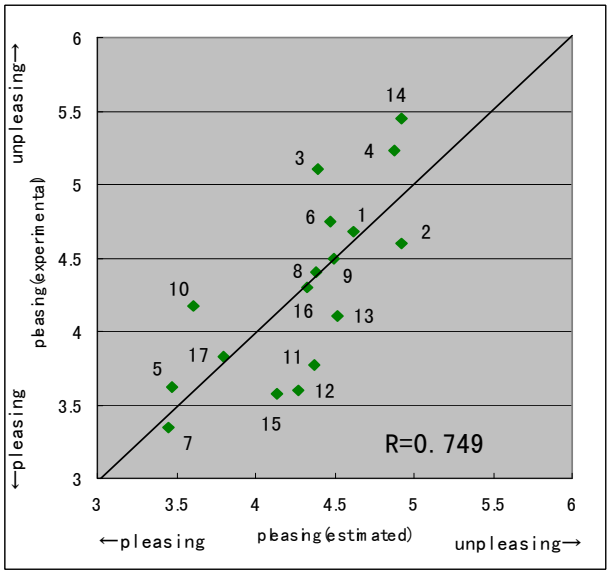

Fig.14 Pleasing values of Germans

4 Conclusion

Seventeen copy machine sounds were evaluated psycho-acoustically in Japan, The United States and Germany. The sounds, which gave good impressions to Japanese, also gave good impressions to Americans and Germans. Americans and Germans, however, were more sensitive to "sharpness" than Japanese. Therefore, certain sounds didn't give the same impression in every country. Evaluated adjective pairs were analyzed by factor analysis. Extracted factors were combinations of powerful, pleasant and metallic factors, which are well known as psycho-acoustical factors. Correlations between "pleasing" and physical values were analyzed. They revealed that, just as with Japanese, Americans and Germans were mostly sensitive to "sound pressure levels." However, the second influential factor for Japanese participants was "roughness," while it was "sharpness" for Americans and Germans. Evaluation formulas for "pleasing" noise using physical values were decided for each country and estimated values of "pleasing"

coincided well with experimentally evaluated values. This suggests that copy machine noise will be evaluated without psychological experiments. The information gathered can possibly be used to adapt copy machine noise to levels that are comfortable to users in different countries.

References

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[5] Fastl, H. and Zwicker, E., Psychoacousitcs: Facts and Models 3rd edition, Springer Verlag (2006)