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LOUDNESS EVALUATION OF VARIOUS KINDS OF NON-STEADY STATE SOUND USING THE METHOD OF CONTINUOUS JUDGMENT BY CATEGORY

Sonoko Kuwano* and Hugo Fastl**

* College of General Education, Osaka University
Toyonaka, Osaka, 560 Japan
** Institute of Electroacoustics, Technical University Munich
Arcistrasse 21, D-8000 München 2, F.R.Germany

INTRODUCTION

The loudness of various non-steady state sounds in our daily life usually shows good correlation with Leq when the duration of sounds is short(1,2). However, even when their Leq values are equal, subjective impressions of sounds with long duration can differ because of other factors. In this experiment, using sounds of long duration from a variety of sources, judgments of instantaneous and overall loudness were investigated in order to examine the relation of loudness to sound source and to Leq, and to examine the effects of the repetition of sounds. Comparison between the judgments made by German and Japanese subjects was also conducted.

EXPERIMENT

Stimulus

Nine kinds of sound source were used. They were: aircraft noise, super express train noise, ordinary train noise, road traffic noise, speech, music, impulsive noise, artificial level-fluctuating noise and steady state pink noise. Four levels were used for each sound source. The duration was about 10 secs. except for impulsive noise.

From these sound sources, aircraft noise, train noise and road traffic noise were selected for repeated presentation, as shown in Table 1. They were presented together with background noise from a residential area at midnight, the level of which was about 30 dBA. The total duration of each stimulus was about 30 minutes. There were 10 stimuli, as shown in Table 1.

Apparatus

The sounds were reproduced from a DAT recorder and presented to subjects using an attenuator, mixer, amplifier, free-field equalizer and headphones (Beyer DT48) in a sound-proof room. Similar equipment was used in Munich and Osaka.

Procedure

Judgments of instantaneous loudness were obtained using the method of continuous judgment by category(3-5). That is, subjects judged the loudness of the sound continuously using seven categories from "very soft" to "very loud", by touching a key on a computer key-board corresponding to one of the categories. Judgments were fed into a computer, and used for analysis. The same type of personal computer (Sharp MZ2500) was used in both laboratories. Subjects made judgments of instantaneous loudness for each of the 10 stimuli. In each case, when judgment of instantaneous loudness was over, a questionnaire was completed, which included questions on the overall loudness of the 30-minute stimulus, the overall loudness of each sound source it contained, and the difficulty of making judgments.

Subjects

One female and seven male German subjects, aged between 27 and 44, and three female and five male Japanese subjects, aged between 19 and 41, all with normal hearing ability, participated in the experiment.

RESULTS AND DISCUSSION

Instantaneous loudness

For each subject and for each stimulus calculation was made of the coefficient of correlation between every 100-msec. section of the computer record of the instantaneous judgments and the Leq values of every 100-msec. section of the stimulus. Statistically significant correlation was found between them in all cases, which indicates the coherence of the judgments.

The instantaneous judgments by the eight subjects were averaged for every 100-msec. section of each stimulus and calculation made of the coefficient of correlation between the mean of instantaneous judgments and the Leq value of every 100 msec. section. As Table 2 shows, in both countries a high correlation was found for all the stimuli. This suggests that instantaneous loudness is determined by the physical value (Leq) of the stimulus.

The average of instantaneous judgments was calculated for each 30-minute stimulus, giving weight to the duration of the use of each category. The relation between the average of instantaneous judgments and the Leq values for the 10 stimuli is shown in Figs.1 and 2. In both countries a high correlation between them is evident.

The average of instantaneous judgments for each sound source was also calculated using the same procedure. In order to examine the effect of repetition, aircraft noise, train noise and road traffic noise were presented repeatedly. The averages of the instantaneous judgments for these sound sources were hardly affected by the order in which they were presented. Examples are shown in Figs.3 and 4. This finding suggests that the instantaneous impression of sounds does not change even when the sounds are presented repeatedly in a situation where subjects pay attention continuously to stimuli.

The relation between overall loudness and instantaneous loudness

The relation between the judgments of overall loudness and the averaged judgments of instantaneous loudness is shown in Fig.5. The figures for overall loudness are much higher than those for the average of instantaneous loudness. The same result was found in one of our previous experiments(5). This suggests that subjects tend to judge overall loudness on the basis of the prominent portion of the stimulus, neglecting the lower level portion. From analysis of the distribution of instantaneous judgments, it was found that only about 25% of the higher category judgments of instantaneous loudness were in the same range as the figures for overall loudness.

Overall loudness

The relation between overall loudness and Leq is shown in Fig.6. There is fairly good correlation between them. Since the Leq values of 30-minute stimuli increase with the number of repetitions, the number of repetitions can affect overall loudness. However, overall loudness of long-term stimuli is judged on the basis of memory and is influenced by various factors. Further experiments using systematic stimulus conditions and more detailed analysis will be needed in order to find an appropriate method for the assessment of environmental noise with mixed sound sources.

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Table 1

St.No.	Number of repetitions		Total N
1.	each sound source	x 1	36
2.	aircraft noise	x 2	40
3.	train noise	x 2	40
4.	road traffic noise	x 2	40
5.	aircraft noise	x 4	48
6.	train noise	x 4	48
7.	road traffic noise	x 4	48
8.	aircraft noise	x 8	64
9.	train noise	x 8	64
10.	road traffic noise	x 8	64

Table 2

St.No.	r (G)	r (J)
1.	.941	.935
2.	.942	.925
3.	.940	.935
4.	.932	.922
5.	.934	.922
6.	.943	.933
7.	.934	.928
8.	.946	.932
9.	.945	.935
10.	.935	.911

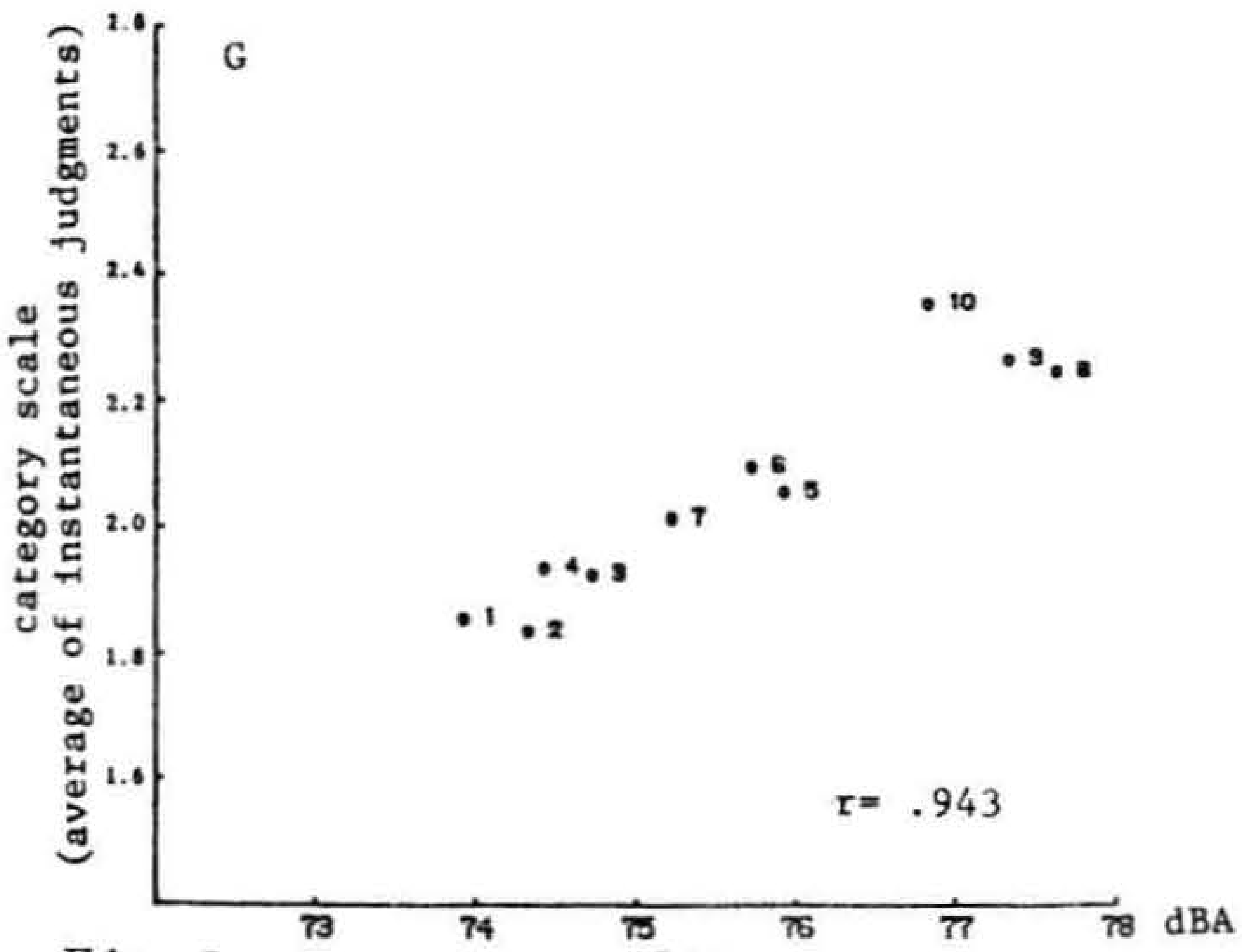

Fig.1

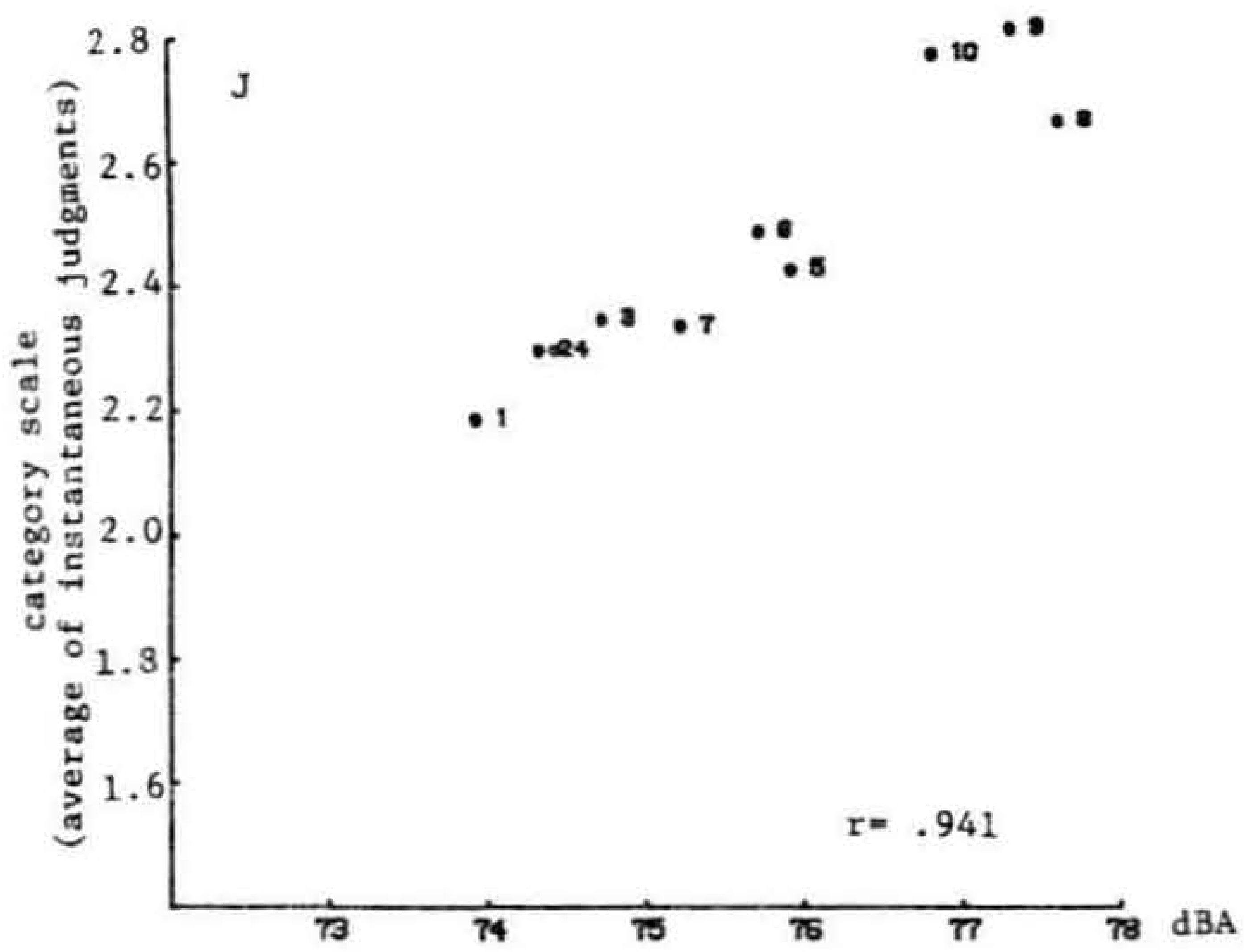

Fig.2

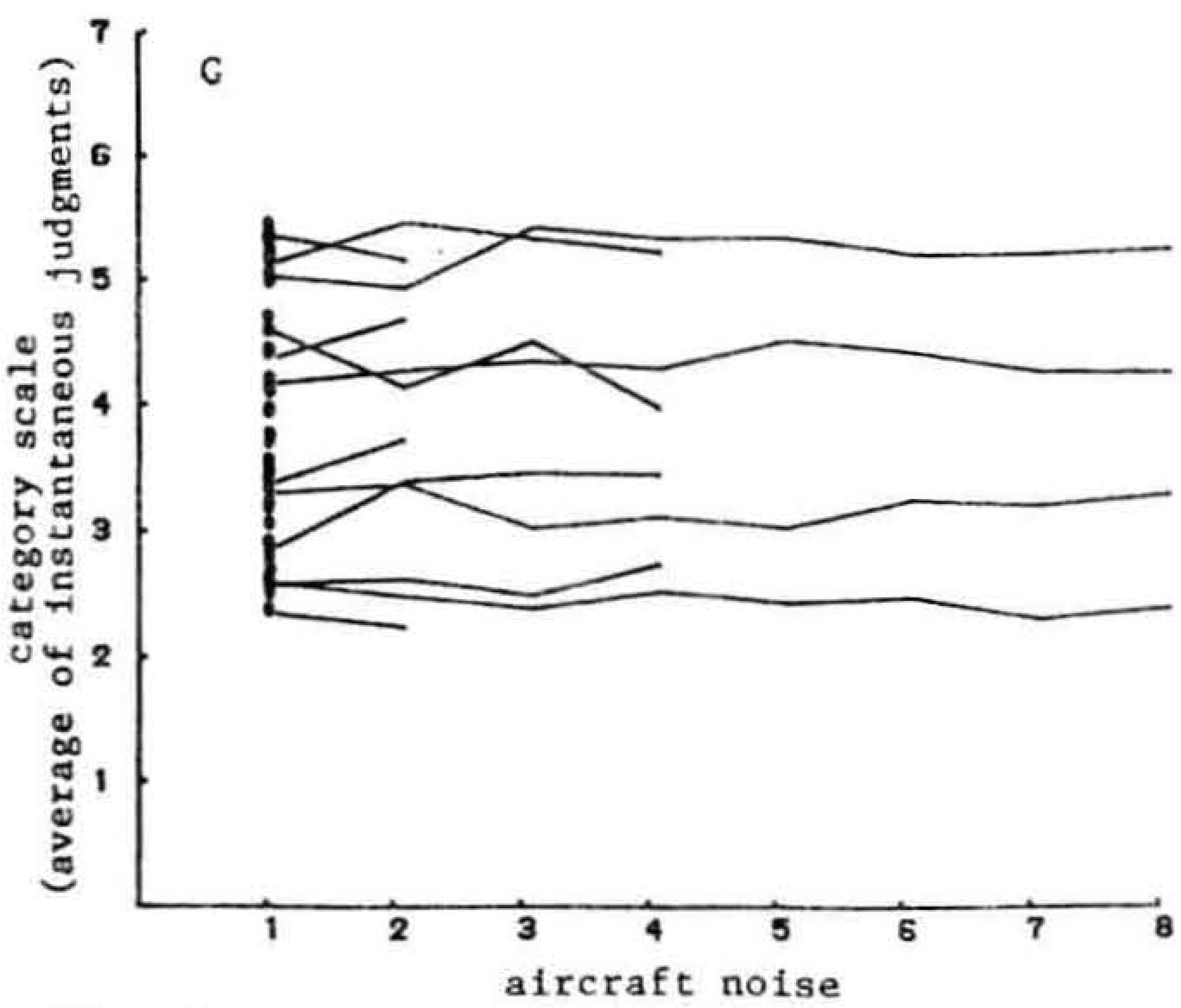

Fig.3

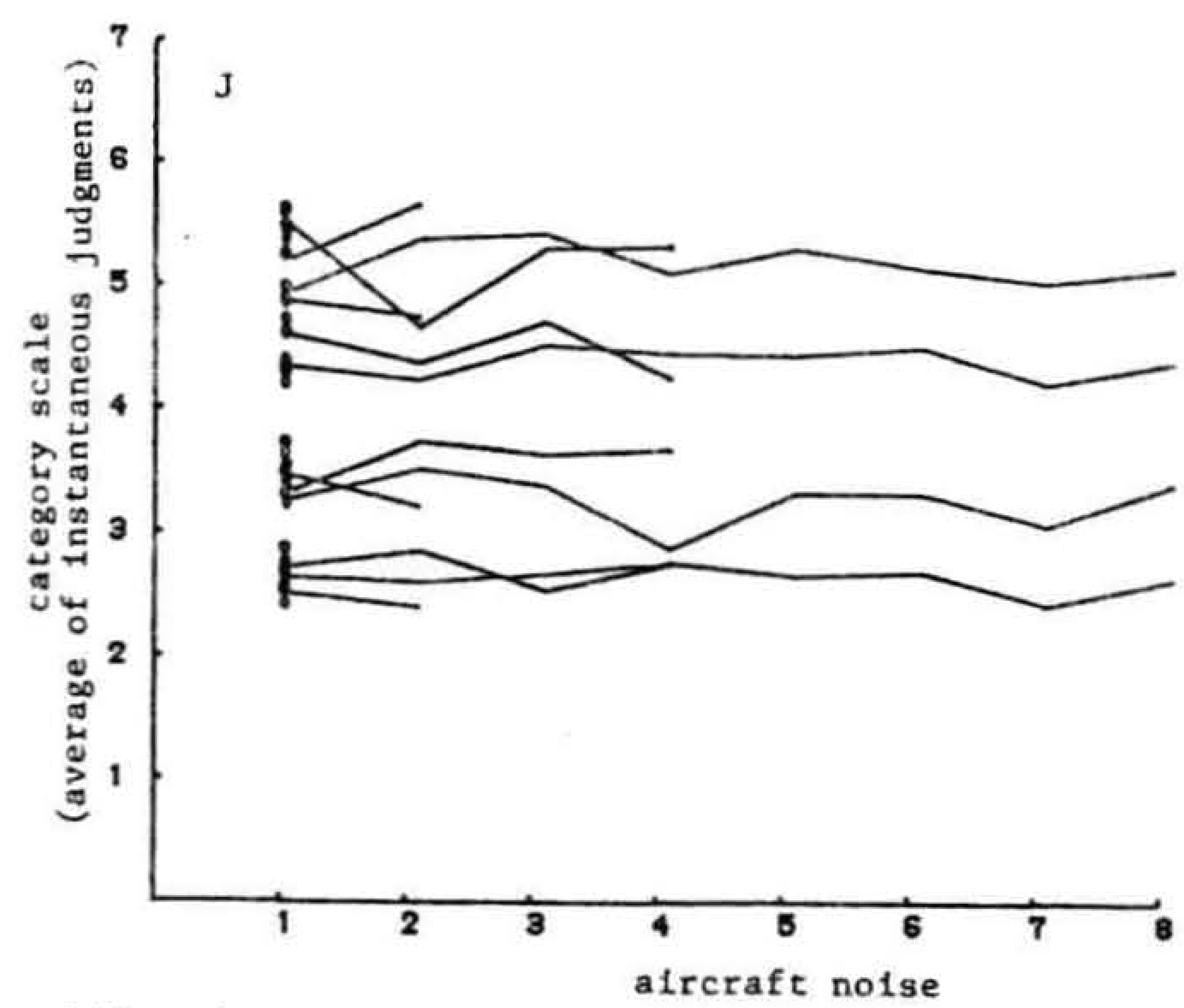

Fig.4

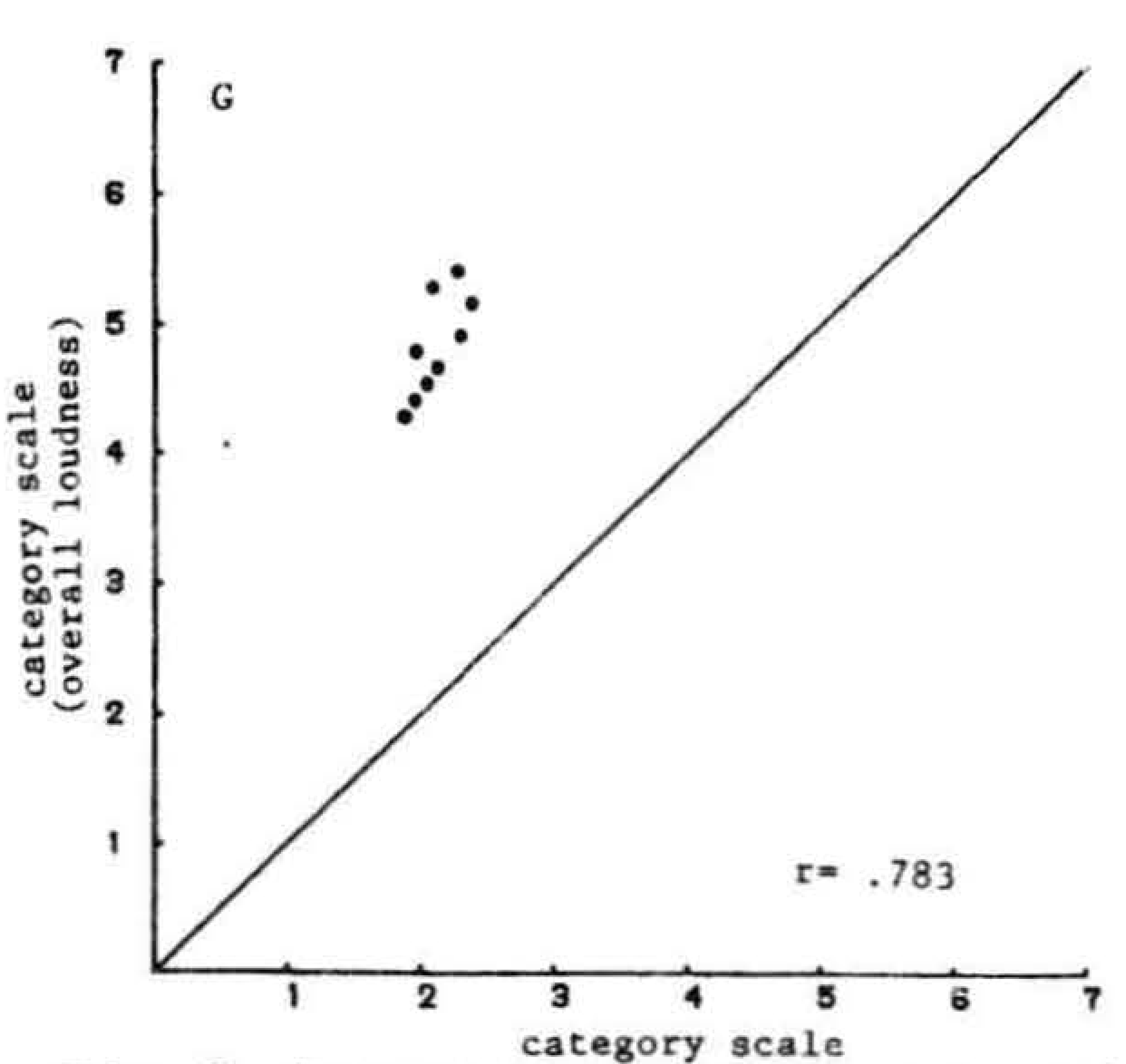

Fig.5

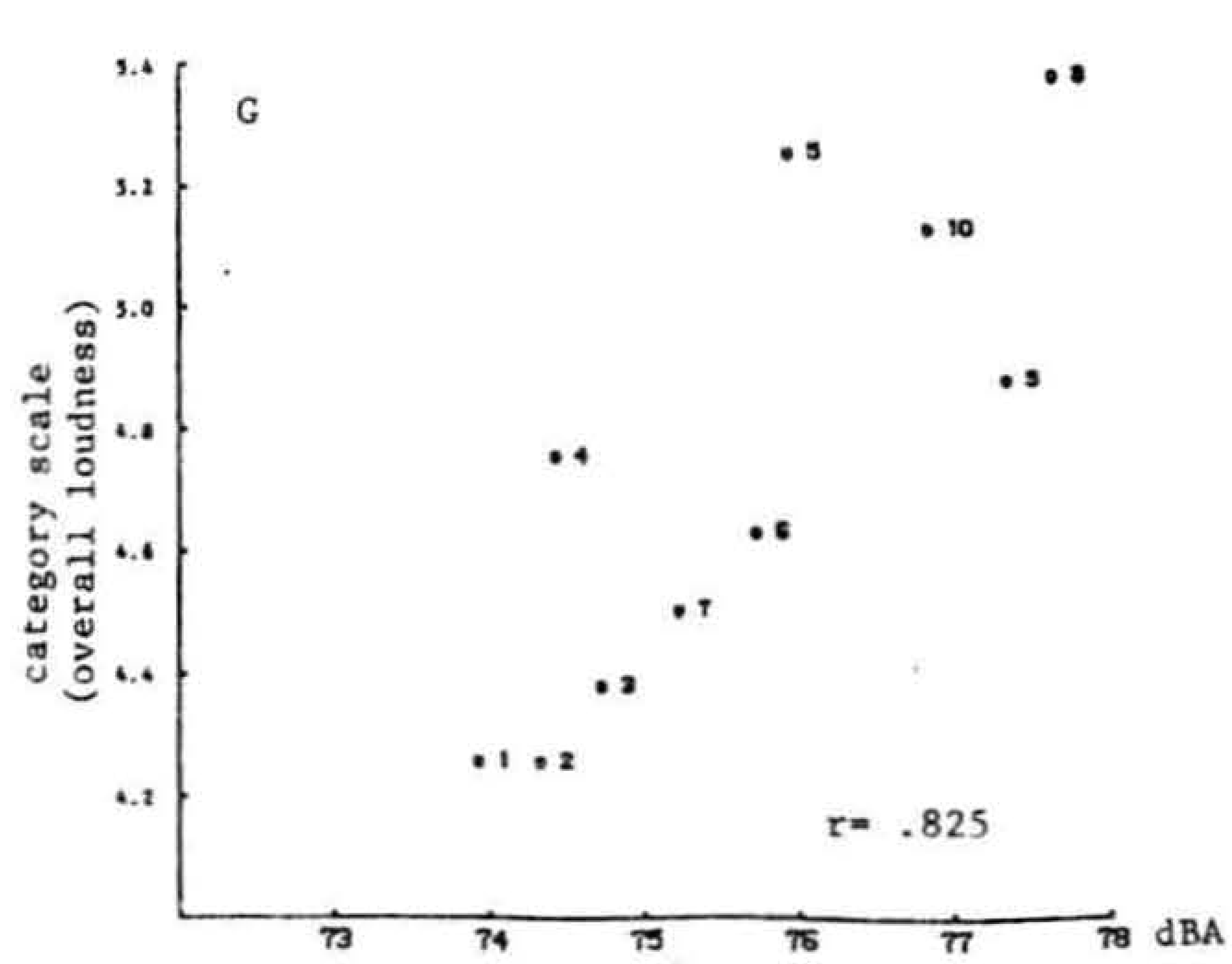

Fig.6