ASPECTS OF DOMESTIC APPLIANCE NOISE

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INTRODUCTION

In recent years, there has been a growing awareness of the noisiness and associated nuisance of domestic appliances. This has added to general concern with environmental noise which hitherto has been focussed on road traffic noise, air craft noise and industrial noise. Evidence for this awareness is the increasing tendency to use the quietness of an appliance as a marketable quality. Furthermore, the EEC has recently issued a directive (86/594/EEC) [1] whereby all new appliances sold in the Common Market Countries will be labelled with their A-weighted sound power level. Despite these developments, there has been relatively little published research about subjective judgements of appliance noise; the adequacy of A-weighted sound power as an indicator of subjective reaction to the noise; and the domestic noise exposures resulting from appliances used in the home. This paper discusses the results of early research in these areas.

SUBJECTIVE JUDGEMENT OF DOMESTIC APPLIANCE NOISE AND THE RELATIONSHIP TO SOUND POWER LEVELS

From the commencement of this research it was known that the EEC directive would recommend labelling of appliances with their sound power level, which is a fundamental physical property of the source alone and gives an adequate description of the noise emission of the appliance.

In order to assess the suitability of sound power level as an indicator of subjective reaction to the noisiness of an appliance, it was necessary to measure sound power levels of domestic appliances to be used subsequently in laboratory tests of objective reaction. These measurements were made at Building Research Establishment in a reverberation chamber according to ISO 3741 - Acoustics - Determination of Sound Power Levels of Noise Source - Precision Methods for Broad-band Sources in Reverberation Rooms [2]. The comparison method was adopted using a Bruel and Kjaer Type 4240 Reference Sound Source, and an array of three microphones. The following appliances were tested: vacuum cleaners; hair driers; food mixers, liquidisers and food processors mixing a bread crumb and water slurry; and fan heaters. Sound power levels were thus calculated from the data obtained (see Table 1 for a summary of sound power levels (A-weighted) of the appliances listed).

Having obtained sound power level measurements for these appliances, it was possible to carry out a series of experiments whereby subjects rated the noisiness of a number of appliances of known sound power level, the purpose being to identify any relationship between sound power level and rating. Much has been written about the subjective assessment of other noise sources, particularly those concerned with forms of transportation. For most of these assessments, different experimental designs were adopted, eg Ohrstrom et al (1980) [3] investigated acute annoyance reaction to different noise sources (lorries, aircraft, mopeds or trains). Forty subjects, female and male, were asked to listen to noises and rate their annoyance using discrete graphic category scale (0-10). Powell and Rice (1975) [4] investigated subjective response to air-

craft noise in different road traffic backgrounds, using two female and ten male subjects, who were asked to rate annoyance on a numerical integer scale from 1 through 9 where 1 = not annoying and 9 = very annoying. Rylander et al (1977) [5] investigated the relationship between traffic noise and annoyance with reference to number of noisy events. One hundred and fifty-five students, male and female, were asked to read a text book of their choice and record their judgements of noise using a questionnaire where noise rating ranged from not annoyed to very annoyed on a four category scale.

Table 1. Summary of appliance SWL(A) noise levels

APPLIANCE	Minimum		Average		Maximum	
	Concrete	Carpet	Concrete	Carpet	Concrete	Carpet
Vacuum Cleaner - upright	78.74	77.02	85.35	81.92	90.85	88.43
Vacuum Cleaner - cylinder	79.49	79.3	81.68	80.52	(84.49) 84.16	(83.06) 81.05
Hairdrier	SUSPENDED		SUSPENDED		SUSPENDED	
- one speed	66.7		72.69		77.1	
- slow speed	69.63		74.57		80.16	
- medium speed	64.8		69.59		74.37	
- fast speed	71.99		80.14		85.55	
Food Mixer	TABLE		TABLE		TABLE	
- slow speed	69.32		72.58		75.84	
Food Mixer - medium speed	74.33		79.03		83.72	
Liquidiser	TABLE		TABLE		TABLE	
- one speed	82.88		83.79		84.7	
- slow speed	76.75		76.75		76.75	
- medium speed	85.19		85.19		95.19	
- fast speed	91.2		91.2		91.2	
Fan Heater - high speed	52.56		56.47		61.32	
Food Processor	TABLE 80.65		TABLE 84.62		TABLE 87.38	

There is a shortage of literature concerning subjective reactions to domestic appliance noise, and there have been a wide range of experimental methodologies adopted in experiments assessing subjective reaction to other noises. Consequently the methodology adopted for these experiments is based largely on advice given by ISVR (who have conducted limited research on domestic appliance noise [6]) and successful aspects of research into subjective reactions to transportation noise.

METHODOLOGY

The main aim of the initial experiments was to determine whether or not subjects rank the noisiness of domestic appliances in the order of their sound power levels in dB(A). Four different appliances of differing sound power levels were chosen - vacuum cleaner, food processor, liquidiser and a hair drier. Because of the difficulties of reproducing accurate recordings of appliance noise, it was decided that the actual appliances would be used and recordings made during the sessions to monitor any changes over time of use. The orders of presentation of the appliances covered all possible combinations of the orders of output SWLs.

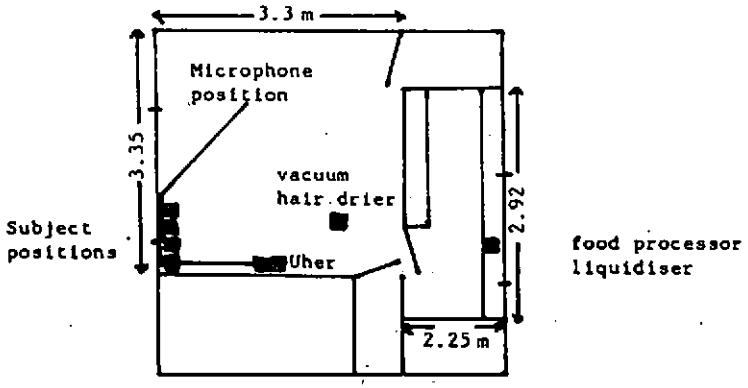
A = Vacuum cleaner
B = Food processor
C = Liquidiser
D = Hair drier

Session A	Session B
ABCD	DABC
DCBA	CVDA
CADB	BCAD
BDAC	ADCB
ADCV	BDAC
BCAD	CADB
CBDA	DCBA
DABC	ABCD

It was suspected that the order of presentation of the appliances might influence ratings given. Therefore appliances were presented in two different orders. Thirty-two subjects were needed for the design, of which nineteen were male, thirteen female.

For these experiments the surroundings should be as realistic as possible to ensure absolute ratings are given by subjects. Therefore a living room and kitchen of a cottage on campus were used for the experiment. The layout of the rooms used can be seen in Figure 1.

Figure 1



Four subjects participated in each test. They were asked to read a general instruction sheet, placed on their chair:

GENERAL INSTRUCTIONS

Thank you for volunteering to participate in this study, which forms part of a PhD project being carried out here at the Open University. The purpose of the study is to investigate subjective responses to the types and levels of sound normally experienced in the home due to the use of electrical appliances. It is hoped that the data gathered will contribute towards the development of an effective method for the sound labelling of domestic appliances.

In this test you will listen to various domestic appliances, and you will be asked to rate each of the appliances according to how noisy you judge it to be. The importance of an honest response cannot be over-emphasised - don't worry about what your neighbour writes - you write what you think!

Subjects were then presented with the four appliances, according to the designed sequence. The hair drier and vacuum cleaner were used by the operator, 2 m from the subjects. To maintain an atmosphere of reality, the food processor and liquidiser were used in the kitchen, at a distance of 4.7 m from subjects. They were operated mixing a bread and water slurry in keeping with research carried out by Jackson and Leventhall (1975) [7]. The sound pressure levels at the location of the listeners' ears were monitored. A Bruel and Kjaer Type 2218 Sound Level Meter was placed at ear height, and connected to a Uher tape recorder type 4400 Report Stereo IC.

During session A, the four appliances were presented, one at a time, for thirty seconds. Subjects were asked to rate the noisiness of each appliance in turn, recording their rating on a rating sheet with a scale of 1 (very quiet) to 7 (extremely noisy). After the four appliances had been presented in session A, subjects were asked to complete a questionnaire containing questions designed to identify noise sensitive individuals. Some questions required personal data about subjects eg occupation, age, etc. Completion of the questionnaire usually lasted about 15 minutes during which time subjects' ears became acclimatised to the relatively quiet background noise level of the lounge. On completion, session B commenced. Subjects were again asked to rate the noise levels of the appliances, but presented in a different order. This process was repeated with different subjects until all orders had been presented.

RESULTS

Spearman rank correlation coefficients were calculated for the ratings. These indicate the correlation between ratings for each session. If the order of presentation of the appliances has no effect on ratings, then correlations should be high. The following results were obtained:

Table 2. Correlation coefficients of ratings for each session

Appliance	Observed r_s value	Significance
Vacuum cleaner	0.86	$P < .01$
Food processor	0.68	$P < .01$
Liquidiser	0.67	$P < .01$
Hair drier	0.73	$P < .01$

Thus it can be concluded that order of presentation does not significantly affect ratings. This result was confirmed by analysis of variance, carried

out for all parts of the experiment (see Summary Table 3).

Table 3. Analysis of variance summary table

Source of variance	Sums of squares	Degrees of freedom	Mean square	F ratios
Appliance	151.73	3	50.6	71.12
Session	0.88	1	0.88	1.73
Subjects	128.37	31	4.14	25.33
Interaction	0.67	3	0.22	1.36
Residual	97.1	217		
Total	378.75	255		

Three hypotheses were advanced:

(1) there will be significant differences between appliance ratings. The critical value for F is 6.17 at the P 1 .001 level of significance. Since the observed value of F for variable A is 71.12, the predicted effect of difference between appliance ratings is significant at this level.

(2) There will be no difference between ratings given in each session. The observed value for session variable of F = 1.73 is not significant at any of the levels since it is smaller than any of the critical values.

(3) There will be no interaction between appliances and sessions. The observed value for the interaction of F = 1.36 is not significant at any of the levels since it is smaller than any of the critical values.

When comparing mean ratings with known sound power levels for the appliances and sound pressure levels recorded at listeners' ears, it appears that subjects ranked in terms of sound power level rather than SPL (sound pressure level) (see Table 4).

Table 4. Mean ratings compared with SWL and SPL

Appliance	Mean rating	SWL dBA	SPL dBA
Vacuum cleaner	5.61	94.38	80.7
Food processor	5.45	87.38	71.8
Liquidiser	4.85	82.88	73.6
Hair drier	3.65	80.16	71.5

This is confirmed by hypothesis 1 of the Analysis of Variance. If subjects were not ranking according to SWL then the ratings for all the appliances might be expected to be similar. However, this is clearly not the case.

SURVEY OF NOISE EXPOSURES RESULTING FROM USE OF DOMESTIC APPLIANCES IN THE HOME

Data for this survey is abstracted from data supplied by Open University students as part of their studies of a second level undergraduate course T234 Environmental Control and Public Health. Part of the course is devoted to a study of noise, and students are issued with type 3 integrating sound level meters. One experiment requires them to measure the Leq of different activities

they are involved in during a 24 hr period. They record Leq values for the different activities, the duration of the measurement period and the duration of the sample. This information is sent to the OU where the relevant data is abstracted.

From data received in the 1986 academic year, it was evident that, as expected, exposure to domestic appliance noise, and thus the proportion of 24 hour noise budget attributable to exposure from appliances, varied considerably (see Table 5).

Table 5. Percentage of 24 hour exposure attributable to domestic appliance noise

Occupation	Range %	Average %	Number
Housewife	11 - 97.5	46	11
Armed forces	14	14	1
Administrators and Managers	0.5	0.5	1
Teachers (nursery-adults)	23-84	50	5
Medical and related, social welfare and other professions and arts	9-31	20	3
Qualified scientists and engineers	0.1-41	10	5
Technical personnel	0.3-73	23	12
Electrical, electronic, engineering and allied trades	9	9	1
Communications, transport: air, sea, road & rail	1.3	1.3	2
Clerical and Office	40-61	42	3
Shopkeepers, sales, services	3-49	20	4
Retired	9	9	1

The domestic appliances resulting in these exposures were the following: TV, radio, stereo, electric kettle, washing machine, tumble drier, vacuum cleaner, extractor fan, food blender, food processor, microwave, food mixer. The exposures of some students were as listeners and non-users of the appliances. Such exposures were lower than those for students who were appliance users. For students who remained in the home the whole day, between 60 and 98% of their exposure was attributable to domestic appliance noise. For those students who worked outside the home, the largest part of their 24 hr exposure was usually determined by journey into work and 'at home' activities.

This data will be available each year of the course, so it is hoped to obtain a larger sample for a more complete survey of noise exposure resulting from use of domestic appliances in the home.

CONCLUSION

The result of the subjective experiments indicated that rating values tended to reflect sound power levels rather than sound pressure levels recorded at the same time, and that subjects ranked accordingly. Future research aims to investigate the following factors:

(a) the noise rating given to an appliance will be affected by whether the subject is using the appliance or listening to it.
(b) Subjects will rate an appliance noise level differently when they are not involved in an activity, eg reading, compared to when they are involved in an activity.
(c) Occupational noise levels will influence ratings.
(d) The amount of time the user/listener is exposed to the appliance noise will influence the ratings.
(e) For appliances with a cyclical mode of operation, ratings will be based on one part of the cycle, eg washing machine, spin cycle.

REFERENCES

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