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JURY TRIALS OF INDIVIDUAL ROAD VEHICLE PASS-BY NOISE

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ABSTRACT

Road traffic is one of the most widespread sources of noise nuisance in England. The control of pass-by noise from individual road vehicles is therefore of obvious importance. This is currently achieved using the A-weighted sound pressure level and measuring the maximum sound level during the full acceleration test referred to in the Department of Transport's Construction and Use Regulations. Limit values are in terms of the maximum permissible sound levels. It has been noted that vehicles with the same test sound levels can sometimes differ in terms of subjective noisiness and over the years the continued use of the maximum A-weighted sound level for control purposes has been questioned. To re-assess the suitability of this noise measure TRRL in collaboration with ISVR conducted a jury experiment where subjects were instructed to rate the noisiness of a range of vehicles as they were driven past a measurement site under different operating conditions. This paper describes the experimental design and analysis procedure adopted and examines the relationship between dB(A) and dB(C) weighted noise measures and average subjective ratings using data from some 2250 individual vehicle pass-by events. Preliminary analysis of the results indicates that A-weighted measures of vehicle noise were generally superior to C-weighted measures for all vehicle classes and operations tested.

INTRODUCTION

Road traffic is one of the most widespread sources of noise nuisance in England (1). In the national survey carried out in 1972 it was found that 89 per cent of the population heard traffic noise in their homes, 23 per cent were bothered by it and for 16 per cent it was considered to be the biggest noise nuisance. This compares with only 8 per cent considering aircraft noise to be the biggest nuisance and less than 2 per cent similarly citing railway noise (1).

At present vehicle noise is controlled by type approval regulations which limit the maximum noise level, in dB(A), that a vehicle type can emit when measured in accordance with the standard procedures set by European Commission Directives recognised by the Department of Transport's Type Approval and Construction and Use Regulations. Over the past decade, the noise limits for different classes of vehicle have been steadily reduced in compliance with progressively more stringent EEC Directives. However, while this has undoubtedly led to improvements in the overall noise emitted by vehicles, it is also felt that some vehicles with the same test sound level can differ appreciably in terms of their subjective noisiness, indicating that the current method of assessment may be insufficient to control the relevant aspects of vehicle noise in all cases. This has led to doubt being expressed about the continuing use of the scale of dB(A) as the sole means of assessing and regulating the noise from road vehicles.

Further doubts about the use of dB(A) are related to the fact that current procedures are based on jury rating trials of individual vehicle pass-by noise which were carried out around 30 years ago. The National Physical Laboratory (NPL) carried out a roadside listening trial in 1959 (2) to compare the readings of sound level meters having different frequency weighting characteristics with subjective noisiness ratings for individual vehicles selected from passing road traffic. This was followed by trials at the Motor Industry Research Association (MIRA) proving ground in 1960 (3). Both sets of trials used listeners stationed outdoors and the experimental design did not provide the opportunity to test for, or to balance, the possible influence on subjective ratings of the order in which the vehicles were presented.

Since these trials, there have been many changes in the vehicle fleet and allowable noise levels have been reduced by up to 10 dB(A) for some classes of vehicle. In addition, subjective preferences may have changed with increasing awareness of environmental quality issues amongst the general public as a whole. Furthermore, the A-weighted noise levels from vehicles measured outside buildings may not represent the noisiness experienced within buildings. This is because the A-weighting under emphasises the importance of low frequency noise, while the facades of buildings tend to attenuate medium frequency noise much more than low frequency noise. Thus the noise heard inside a room may bear little relation to the A-weighted noise level measured outside a building.

A final point to note is that the A-weighting does not accord to the known frequency sensitivity of the human ear at the higher sound levels encountered with road traffic noise exposure. For these sound levels the sensitivity of the human ear exhibits a much flatter frequency response which more closely resembles the dB(C) weighting.

These various considerations point to the need to re-evaluate the continuing use of the dB(A) scale as the sole means of assessing the noise produced by road vehicles. With this objective, the Department of Transport commissioned the Transport and Road Research Laboratory (TRRL) to conduct a new series of jury rating trials. TRRL placed a research contract with the Institute of Sound and Vibration Research (ISVR) to develop an appropriate experimental design strategy, to assist with the trials, and to carry out an initial analysis of the resulting data. This paper summarises the experimental design adopted and the results of the preliminary analysis. Further detailed analysis of the data archive is continuing at TRRL.

THE 1988 JURY RATING TRIALS

The current trials were carried out during August 1988 at the TRRL test track. In order to examine the responses of people exposed to noise heard indoors, a single storey building was constructed alongside the test track with a listening room to accommodate the indoor juries. A plan of the site showing the position of the building, listening room, the test track and the location of the outdoor jury is shown in Figure 1.

The building was of conventional construction, ie cavity wall with brick elevations, and with an insulated flat roof and a standard single glazed window facing the test track. The indoor listening room was larger than average for typical domestic property, in order to accommodate up to 20 listeners at a time. The "bungalow" had a lobby for coats and refreshments and a small recording/observation room fitted with CCTV monitors giving an overall view of the test site and track. A paved area was provided for the outdoor listeners. Precision grade condenser microphones were positioned at the centre of the outdoor listening position and at three representative positions in the indoor listening room. The positions of the microphones are shown in plan on the figure. An area of the test track adjacent to the bungalow was marked off with white lines, cones and safety barriers to ensure vehicles kept to the same path each time which was approximately 8.5m from the front facade of the bungalow. The test track at this point had a slight gradient which allowed tests to be carried out with vehicles travelling both uphill and downhill.

The vehicles used in the trials comprised a broad range of vehicle types and were selected to give a range of noise emission characteristics incorporating both in-service "fleet" vehicles as well as production prototypes with low noise characteristics. Motorcycles were not included. The vehicles were subdivided into four groups of 8 vehicles according to the following classifications:-

Heavy vehicles - i.e. articulated vehicles with a gross allowable vehicle weight between 16 and 38 tonnes.

Medium vehicles - i.e. vehicles with a gross weight between 7.5 and 16 tonnes.

Light vehicles - i.e. cars and vans up to 3.5 tonnes. This group included a range of cars with engine powers in the range 40 - 170 kW.

Mixed vehicles - This group included a selection of vehicles taken from the preceding three groups.

During each test day, all vehicles within the selected group were driven past the bungalow in convoy with a separation between vehicles of approximately 30 seconds. This allowed time for jury members to decide on their ratings whilst avoiding the possibility of large gaps occurring. For each group of eight vehicles the first two vehicles repeated their runs at the end of each convoy to give a total of 10 vehicle pass-by events in all. There were 24 convoys on each test day and these were divided into 4 blocks of 6. The first convoy of any block had mixed vehicle operations to demonstrate to the juries the range of noisiness to be encountered during the rest of the block. In each subsequent convoy vehicle operations were altered. However within a particular convoy all vehicle operations were similar. In this way each vehicle was tested under 6 different operating conditions; low, medium, and high steady speeds, using different gears and engine speeds to produce a wide range of noise levels and spectra; maximum acceleration from a standard entry speed to simulate approximate type approval test conditions for each vehicle class; and a 15 second idling condition followed by a maximum acceleration pull-away from rest. Each operation was repeated for uphill and downhill directions.

After one block of convoys in a particular direction the indoor and outdoor groups of jurors changed places and a further block of convoys was presented with vehicles running in the same direction. In this way separate indoor and outdoor ratings of essentially the same pass-by event were made by each listener. Where possible, the steady speeds and idling engine rpm were selected to accentuate the differences in the frequency spectra of the sounds as heard indoors and outdoors.

The rating scale used by the juries employed a scale numbered linearly from 0 to 9 and labelled "increasing noisiness". An example of the rating form used for each vehicle convoy is shown in Figure 2. Each listener was, therefore, asked to give an assessment of the relative noisiness of each vehicle event using the full range of the scale. The precise definition of the term "noisiness" was left for the listeners to interpret for themselves, however, in the instructions given to each jury it was made plain that the ratings should, as far as possible, relate to the sound made by the vehicle and not be influenced by the appearance of the vehicle or the listening context.

The listeners were recruited by TRRL at random by postal invitation using the local electoral register. The invitations stated that 'normal' hearing was a requirement for the tests, otherwise no other selection criteria were involved. Listeners were issued with the noisiness rating sheets for each pass-by convoy as required. A number of demonstration pass-bys were made during the course of each test day for scale orientation purposes. Listeners were explicitly instructed to adjust their use of the scale to take account of the range of noisiness encountered during the first few vehicle pass-bys. There was a series of demonstration runs for rating scale orientation at the start of each block of convoys whenever the listeners were moved from outdoors to indoors and vice versa. All listeners were allowed to view the vehicles as they drove past the test site, but , as mentioned above, they were specifically instructed to ignore the visual appearance as much as possible and to concentrate solely on the sound of the vehicles when selecting their ratings.

There were two test days for each vehicle class, with the second day being operated in reverse order to the first day in order to balance out any residual order effects. Between 25 and 30 listeners were recruited for each trials day to allow for a minimum attendance of 20, i.e. a minimum of 10 in each group of listeners. Each test day had to accommodate 8 vehicles and 6 operations in both uphill and downhill directions for both indoor and outdoor listening conditions. This required each listener to rate 240 vehicle pass-bys, (ie. 10 vehicles (including 2 repeats) in each convoy times 6 convoys times 2 directions, up or downhill, for two positions, indoor and outdoor. This apparently very demanding task was accomplished by dividing up the trials into blocks of convoys with ample refreshment and rest periods between blocks. Each block of 6 convoys took approximately one hour to complete and therefore listeners were on-site for about 6 hours. Indoor and outdoor listeners were changed over during the rest periods between blocks.

There were a number of delays due to vehicle problems, weather conditions and noises emanating from outside the test track site. A significant proportion of the data from the first day of trials had to be discarded due to an unsuspected technical fault, but the remaining data was sufficiently comprehensive to allow the objectives to be achieved. There were approximately 2,250 individual vehicle pass-bys and approximately 70,000 individual noisiness ratings taken during the course of the trials.

All pass-bys were recorded using calibrated two-channel digital audio tape recorders. These recorders have a dynamic range in excess of 90 dB and a flat frequency response from 2 Hz to 20 kHz. One tape recorder was used for simultaneous recording of the outdoor and the centre indoor microphone signals, and a second tape recorder was used for the other two indoor microphone signals. The recorders were synchronised with a remote controller at the beginning and end of each convoy. In addition , two graphic level recorders were used to record A-weighted sound levels at the outdoor and indoor centre microphone positions and the resulting charts were continuously annotated for event identification. The recordings were analysed at ISVR using a four channel computer-based sound level meter system. The system recorded the maximum level and the single event level (SEL)*, both A-weighted and C-weighted, for two signal channels simultaneously. The recordings were monitored using headphones to detect the beginning and end of each event to allow manual triggering of the measurement system and to detect spurious sounds not connected with the vehicle pass-bys. Automatic triggering was found to be unreliable, and this set a limit to the amount of data which could be analysed in full. A number of sample comparisons of the three indoor microphone signals were made which showed that the centre indoor microphone channel gave a good representation of the other two channels in respect of A-weighted SEL, but that there were some differences when considering the maximum A-weighted level instead of SEL, and further, that the differences were greatest when using C-weighted levels. These differences are attributable to the effects of the indoor listening room acoustics, and are under further study at TRRL.

Each vehicle pass-by was treated as a unique operation for statistical analysis. The noisiness ratings were analysed on an individual basis to obtain mean subjective scores for each vehicle pass-by for each listening condition (indoors or outdoors). The mean ratings were then transferred to a second set of computer files for comparison with the previously entered physical measurement data, and further subsets of the data were created to exclude demonstration and repeat pass-bys for subsequent analysis.

RESULTS

The data archive allows for a large number of different analyses, some of which are currently in progress at TRRL, but the preliminary analysis reported here was intended only to compare the relative efficacy of the four candidate noise measures as described above to correlate with subjective noisiness as reported by both indoor and outdoor juries. This was done using correlation analysis. Although correlation coefficients do not show cause and effect and

*SEL (Single Event Level) is defined as the constant level which, if maintained for 1 second, would produce the same weighted noise energy as the actual event itself.

can also be misleading if variable range and the number of observations are not taken into account, they nevertheless indicate the strength of the relationships between different variables, and are, therefore, valuable for revealing the relative strengths and weaknesses of the noise measures examined.

Tables 1, 2, 3, and 4 below give the correlation coefficients obtained for all four noise measures studied and for the heavy, mixed, medium and light vehicle classes respectively. The tables are broken down into all modes of operation , (i.e. the moving acceleration condition, the pull away from rest condition, the three steady speed operations grouped together, and the idling operations. The columns of coefficients represent the correlations obtained by comparing outside noise measurements with outside ratings and inside measurements with both inside and outside ratings. The three unbracketed columns of figures are the actual correlation coefficients obtained for each test condition . These values cannot be directly compared for significant differences using the usual approach of comparing differences between coefficients with the standard error of the differences since it cannot be assumed that the correlation coefficients are taken from a normal distribution. The degree of uncertainty will, of course, depend upon the size of the sample from which the correlation coefficient is derived. It is, however, safe for most practical cases to transform the correlation coefficients to Fisher z values, and to refer the differences of these values to the standard error of their difference. The bracketed figures given in the tables are the z transforms of the correlation coefficients obtained in each case. At the head of each block of coefficients is a statement of the z value that implies 95% confidence in a difference being real. Using this value, therefore, it is possible to deduce whether the transformed coefficients obtained within each block are significantly different. It should be stressed , however, that the quoted confidence intervals can only be used to determine the significance (or otherwise) of the differences between coefficients in the specified block. They should not be used to investigate the relative strength of the relationships between subjective and objective measures across blocks, i.e. between different vehicle classes or operations.

DISCUSSION

Taken overall, the complete data set shows that the single measures examined which are based on the scale of dB(A) are, in most cases, superior to equivalent measures constructed using C-weighting. The differences are not, however, significant in all cases. A further general point is that there was a strong relationship between the A-weighted SEL or the A-weighted maximum level as measured outdoors, and the mean subjective noisiness ratings both indoors and outdoors.This implies that the current practice of measuring outdoors both for vehicle type approval and for the assessment of entitlement to noise insulation against road traffic noise would appear to be justified in terms of assessing the nuisance caused for both indoor and outdoor listeners.

Generally, the correlations between subjective ratings indoors and measurements indoors were significantly lower than the correlations between measurements outdoors and ratings indoors. This was partly attributable to the fact that the indoor measurements were more susceptible to interference due to inadvertent sounds made by the listeners than the outdoor measurements because the indoor levels were much lower. In addition, the indoor room centre microphone position was not found to be representative of the 15 to 20 indoor jury seating positions. This was particularly noted for low frequency noise due to the variation in the internal noise field caused by room mode effects. In contrast, the recordings taken at the outdoor microphone position were found to accurately represent the sound heard by all the jury members located outdoors and were not subject to similar field strength variations. The prospects for improving the representation of the indoor noise levels is currently being explored by TRRL.

In general, the data shows that the SEL dB(A) measures gave higher correlations than the corresponding maximum dB(A) levels. This could be explained by the possibility that the duration of the noise generated as a vehicle passes by is related to the overall subjective noisiness rating of the event. Clearly, the maximum level, Lmax, is not sensitive to duration effects whereas the SEL is conditioned both by duration and the maximum level emitted by the source during the event. A further possible explanation is that the SEL provides a better representation of the average maximum noise level of the pass-by than Lmax. For example, the Lmax is particularly sensitive to short duration transients occurring during the region where the maximum noise occurs which can significantly distort the Lmax level deduced from the event, whereas the SEL, by virtue of the much longer averaging time, will tend to be relatively insensitive to short duration transients. Again these physical differences between the two scales may be directly related to the way people perceive, and hence rate, the noisiness of vehicles.

On the basis that low frequency room resonances contribute to the C-weighted levels recorded indoors, it might have been expected that a higher correlation with subjective noisiness indoors would have resulted using C-weighted measures. While this preliminary analysis clearly does not support this contention, further investigation would be worthwhile. This is because the difficulties encountered in repeating vehicle operating conditions precisely led to considerable variability in the extent to which low frequency indoor resonances were excited even though some engine idling speeds were specially selected in an attempt to excite prominent room modes indoors. In addition, the occasions on which prominent room resonances actually occurred were relatively few and would, as a result, be masked by the general mass of data where significant room resonances did not occur to any great extent. TRRL are currently examining the usefulness of indices based on both dB(A) and dB(C) measures that might be sensitive to these effects and so might be more successful than dB(A) alone in accounting for subjects' ratings.

Finally, it is clear from this stage of the analysis that although the correlations between the noisiness ratings, both indoors and outdoors, with either A-weighted SEL or Lmax measured outdoors were reasonably high for this type of subjective study, there still remains a substantial amount of the variance in subjective rating unexplained by any of the physical measures tested. It is possible, therefore, that higher correlations could be achieved by using different frequency weightings, combinations of noise measures, or by using other noise indices that take into account other components in the vehicle noise signature.

CONCLUSIONS

1. A preliminary analysis of the jury experiment data archive revealed that A-weighted measures of vehicle noise were generally superior to C-weighted measures for all vehicle classes and operations tested. In particular there was a reasonably strong correlation between the values of Lmax dB(A) and SEL dB(A) measured outside and subjective ratings measured both outdoors and indoors.

2. The correlations between acoustic measures taken indoors and subjective ratings indoors were not as high due mainly to the difficulty in determining the indoor noise levels applicable for all jury member positions inside the listening room.

3. Measurements of the single event level (SEL) gave consistently higher correlations with subjective noisiness than Lmax, which may be significantly related to the way people perceive, and hence rate, the noisiness of vehicles.

4. It is possible that higher correlations with ratings could be achieved by using different weightings and noise indices which take into account other components in the vehicle noise signature.

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Any views expressed are not necessarily those of the Department of Transport.

Table 1 Correlation coefficients for heavy vehicles

Noise measure	Outside measurements with outside scores		Outside measurements with inside scores		Inside measurements with inside scores	
	r	(z score)	r	(z score)	r	(z score)
Moving acceleration (n=32) Difference in z scores for 95% confidence >= 0.526						
Max dB(A)	.7804	(1.045)	.5098	(0.562)	.4530	(0.488)
Max dB(C)	.6824	(0.833)	.4541	(0.489)	.3637	(0.381)
SEL dB(A)	.7895	(1.069)	.4521	(0.487)	.4600	(0.497)
SEL dB(C)	.7095	(0.885)	.3951	(0.417)	.3773	(0.396)
Pull-away (n=32) Difference in z scores for 95% confidence >= 0.526						
Max dB(A)	.8607	(1.295)	.7265	(0.920)	.6822	(0.832)
Max dB(C)	.6799	(0.828)	.6727	(0.815)	.5230	(0.580)
SEL dB(A)	.8874	(1.408)	.7620	(1.000)	.8028	(1.105)
SEL dB(C)	.7709	(1.021)	.7307	(0.929)	.5852	(0.670)
Steady speed (n=95 or 96) Difference in z scores for 95% confidence >= 0.289						
Max dB(A)	.8410	(1.225)	.6700	(0.810)	.6980	(0.863)
Max dB(C)	.6750	(0.820)	.5360	(0.599)	.3750	(0.394)
SEL dB(A)	.9060	(1.505)	.7370	(0.944)	.7102	(0.887)
SEL dB(C)	.6860	(0.840)	.5240	(0.582)	.3700	(0.388)
Idling (n=32) Difference in z scores for 95% confidence >= 0.526						
Max dB(A)	.8665	(1.317)	.7915	(1.074)	.5462	(0.612)
Max dB(C)	.5375	(0.600)	.5446	(0.610)	.6295	(0.740)
SEL dB(A)	.8981	(1.461)	.8113	(1.130)	.7490	(0.970)
SEL dB(C)	.6148	(0.716)	.6135	(0.714)	.6447	(0.765)
All conditions (n=192 or 191) Difference in z scores for 95% confidence >= 0.202						
Max dB(A)	.8889	(1.417)	.8461	(1.242)	.8140	(1.139)
Max dB(C)	.7745	(1.032)	.6973	(0.862)	.6140	(0.715)
SEL dB(A)	.9092	(1.523)	.8533	(1.268)	.8392	(1.217)
SEL dB(C)	.7915	(1.075)	.7008	(0.869)	.6110	(0.711)

Table 2 Correlation coefficients for mixed vehicles

Noise measure	Outside measurements with outside scores r	(z score)	Outside measurements with inside scores r	(z score)	Inside measurements with inside scores r	(z score)
Moving acceleration (n=61, 63 or 64) Difference in z scores 95% for confidence >= 0.368						
Max dB(A)	.8660	(1.315)	.7919	(1.075)	.6654	(0.802)
Max dB(C)	.7494	(0.970)	.6742	(0.817)	.5299	(0.589)
SEL dB(A)	.9077	(1.513)	.8035	(1.107)	.7582	(0.991)
SEL dB(C)	.8417	(1.226)	.7429	(0.956)	.6356	(0.750)
Pull-away (n=60, 61 or 64) Difference in z scores for 95% confidence >= 0.371						
Max dB(A)	.8366	(1.208)	.7897	(1.069)	.7067	(0.880)
Max dB(C)	.7120	(0.891)	.6900	(0.848)	.6170	(0.720)
SEL dB(A)	.8489	(1.251)	.7929	(1.078)	.7618	(0.999)
SEL dB(C)	.7910	(1.074)	.7540	(0.982)	.6690	(0.809)
Steady speed (n=179,183 or 192) Difference in z scores for 95% confidence >= 0.209						
Max dB(A)	.9150	(1.557)	.8680	(1.325)	.7820	(1.051)
Max dB(C)	.6290	(0.740)	.6100	(0.709)	.4170	(0.444)
SEL dB(A)	.9370	(1.713)	.8820	(1.385)	.8460	(1.242)
SEL dB(C)	.6340	(0.748)	.6200	(0.725)	.4107	(0.436)
Idling (n=64) Difference in z scores for 95% confidence >= 0.359						
Max dB(A)	.8935	(1.437)	.8852	(1.398)	.7046	(0.875)
Max dB(C)	.6490	(0.774)	.6530	(0.781)	.6790	(0.827)
SEL dB(C)	.8983	(1.462)	.9059	(1.502)	.8427	(1.229)
SEL dB(C)	.6120	(0.712)	.6260	(0.735)	.6250	(0.733)
All conditions (n=365,367,371 or 384) Difference in z scores for 95% confidence >= 0.146						
Max dB(A)	.9022	(1.482)	.8890	(1.417)	.8230	(1.166)
Max dB(C)	.7180	(0.904)	.6870	(0.842)	.5810	(0.664)
SEL dB(A)	.9220	(1.600)	.8980	(1.462)	.8730	(1.346)
SEL dB(C)	.7340	(0.937)	.6970	(0.861)	.5530	(0.623)

Table 3 Correlation coefficients for medium vehicles

Noise measure	Outside measurements with outside scores r	(z score)	Outside measurements with inside scores r	(z score)	Inside measurements with inside scores r	(z score)
Moving acceleration (n=64) Difference in z scores for 95% confidence >= 0.359						
Max dB(A)	.7380	(0.946)	.6900	(0.848)	.4209	(0.448)
Max dB(C)	.4794	(0.522)	.4485	(0.482)	.2919	(0.300)
SEL dB(A)	.7857	(1.059)	.6937	(0.854)	.4381	(0.469)
SEL dB(C)	.4791	(0.521)	.3829	(0.403)	.2081	(0.211)
Pull-away (n=64) Difference in z scores for 95% confidence >= 0.359						
Max dB(A)	.7231	(0.913)	.6943	(0.855)	.6953	(0.857)
Max dB(C)	.4260	(0.455)	.3950	(0.418)	.3480	(0.363)
SEL dB(A)	.7893	(1.068)	.7104	(0.887)	.7415	(0.953)
SEL dB(C)	.6070	(0.704)	.5480	(0.616)	.4900	(0.536)
Steady speed (n=189,190 or 192) Difference in z scores for 95% confidence >= 0.203						
Max dB(A)	.8950	(1.447)	.8580	(1.286)	.7997	(1.097)
Max dB(C)	.5641	(0.638)	.5171	(0.572)	.5028	(0.552)
SEL dB(A)	.9270	(1.637)	.8760	(1.358)	.8370	(1.210)
SEL dB(C)	.6321	(0.744)	.5565	(0.627)	.5081	(0.560)
Idling (n=64) Difference in z scores for 95% confidence >= 0.359						
Max dB(A)	.8510	(1.260)	.8290	(1.185)	.8021	(1.103)
Max dB(C)	.7180	(0.904)	.7430	(0.957)	.7355	(0.940)
SEL dB(A)	.8491	(1.252)	.8568	(1.280)	.8391	(1.217)
SEL dB(C)	.6710	(0.813)	.7230	(0.914)	.7090	(0.885)
All conditions (n=381,382 or 384) Difference in z scores for 95% confidence >= 0.143						
Max dB(A)	.8940	(1.442)	.9030	(1.488)	.8640	(1.307)
Max dB(C)	.6920	(0.852)	.6980	(0.863)	.6603	(0.792)
SEL dB(A)	.9170	(1.570)	.8970	(1.457)	.8765	(1.359)
SEL dB(C)	.7335	(0.935)	.7119	(0.890)	.6371	(0.752)

Table 4 Correlation coefficients for light vehicles

Noise measure	Outside measurements with outside scores		Outside measurements with inside scores		Inside measurements with inside scores	
	r	(z score)	r	(z score)	r	(z score)
Moving acceleration (n=64) Difference in z scores for 95% confidence >= 0.359						
Max dB(A)	.7270	(0.922)	.7000	(0.867)	.5422	(0.607)
Max dB(C)	.5800	(0.662)	.5140	(0.568)	.4230	(0.451)
SEL dB(A)	.7876	(1.064)	.7188	(0.904)	.6169	(0.719)
SEL dB(C)	.6882	(0.844)	.5558	(0.626)	.3864	(0.407)
Pull-away (n=60,61 or 64) Difference in z scores for 95% confidence >= 0.371						
Max dB(A)	.7859	(1.059)	.8268	(1.177)	.7460	(0.964)
Max dB(C)	.7298	(0.927)	.8009	(1.100)	.4981	(0.546)
SEL dB(A)	.7861	(1.060)	.8065	(1.116)	.8531	(1.266)
SEL dB(C)	.7391	(0.947)	.8299	(1.186)	.5781	(0.659)
Steady speed (n=186,188 or 192) Difference in z scores for 95% confidence >= 0.205						
Max dB(A)	.9510	(1.842)	.9320	(1.672)	.8570	(1.282)
Max dB(C)	.8060	(1.116)	.7910	(1.074)	.4213	(0.449)
SEL dB(A)	.9640	(1.997)	.9453	(1.784)	.8593	(1.289)
SEL dB(C)	.7323	(0.933)	.7178	(0.902)	.3288	(0.341)
Idling (n=63 or 64) Difference in z scores for 95% confidence >= 0.362						
Max dB(A)	.9230	(1.609)	.9291	(1.651)	.8750	(1.354)
Max dB(C)	.7602	(0.996)	.7823	(1.050)	.7249	(0.917)
SEL dB(A)	.9318	(1.670)	.9398	(1.734)	.8770	(1.363)
SEL dB(C)	.7475	(0.966)	.7699	(1.019)	.7490	(0.971)
All conditions (n=373,377 or 384) Difference in z scores for 95% confidence >= 0.144						
Max dB(A)	.9180	(1.576)	.9280	(1.644)	.8500	(1.256)
Max dB(C)	.7790	(1.043)	.8040	(1.110)	.5630	(0.637)
SEL dB(A)	.9294	(1.652)	.9319	(1.671)	.8740	(1.350)
SEL dB(C)	.7651	(1.007)	.7809	(1.046)	.5200	(0.576)

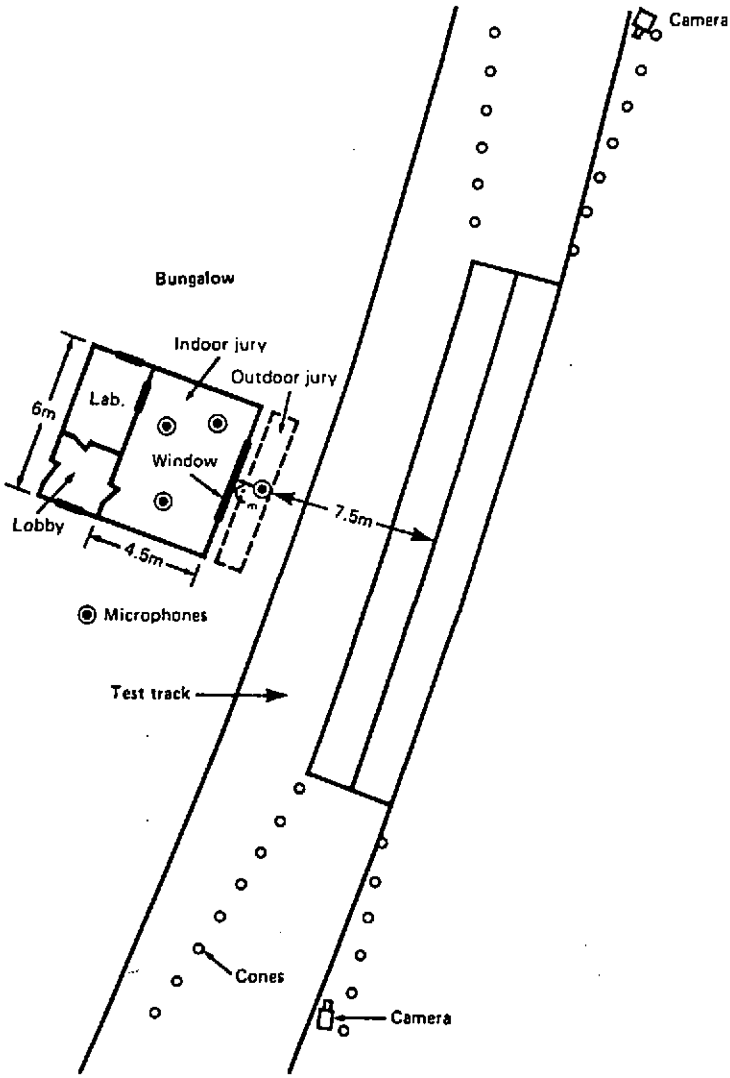

Fig.1 Plan of test track and listening room facility

NOISINESS RATING FORM

Name: Date:

Code:

Sound	→ Increasing Noisiness →									
1.	0	1	2	3	4	5	6	7	8	9
2.	0	1	2	3	4	5	6	7	8	9
3.	0	1	2	3	4	5	6	7	8	9
4.	0	1	2	3	4	5	6	7	8	9
5.	0	1	2	3	4	5	6	7	8	9
6.	0	1	2	3	4	5	6	7	8	9
7.	0	1	2	3	4	5	6	7	8	9
8.	0	1	2	3	4	5	6	7	8	9
9.	0	1	2	3	4	5	6	7	8	9
10.	0	1	2	3	4	5	6	7	8	9

Figure 2.