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Effects of Road-Traffic Background Noise on Judgments of Individual Airplane Noises

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SUMMARY

Two laboratory experiments were conducted to investigate the effects of road-traffic background noise on judgments of individual airplane flyover noises. The major differences between the experiments were the interstimuli periods between airplane-noise events and completeness of the experimental design across traffic-noise types and levels.

In the first experiment, 27 subjects judged a set of 16 airplane flyover noises in the presence of traffic-noise sessions of 30-min duration consisting of the combinations of 3 traffic-noise types and 3 noise levels. In the second experiment, 24 subjects judged the same airplane flyover noises in the presence of traffic-noise sessions of 10-min duration consisting of the combinations of 2 traffic-noise types and 4 noise levels.

In both experiments the airplane noises were judged less annoying in the presence of high traffic-noise levels than in the presence of low traffic-noise levels. The maximum reduction in airplane-noise annoyance was equivalent to a 5-dB reduction in airplane-noise level. An interaction between airplane-noise level and traffic-noise level was found which indicated that airplane-noise annoyance was not a monotonically increasing function of the ratio of airplane-noise level to traffic-noise level.

INTRODUCTION

During the past 20 years considerable information has been generated concerning annoyance due to aircraft noise. Reference 1 includes a comprehensive review of such research and how various laboratory and field studies have resulted in the proliferation of noise rating scales (such as effective perceived noise level) and noise exposure indices (such as noise exposure forecast) which are presently used to measure or certify the noise of individual aircraft and to predict community reaction to aircraft-noise environments.

Most of the laboratory studies have centered around only one aspect of the aircraft-noise problem, that is, the annoyance, or more properly, the noisiness or unpleasantness of individual aircraft sounds. Although this information is of great importance for determining the relative effects of different types of aircraft, very little insight is provided as to how various "mixes" and numbers of these aircraft types and other noises combine over periods of time to affect community annoyance.

Social survey studies, on the other hand, although providing information on annoyance under real environmental conditions, suffer from a lack of precision noise measurement which the laboratory provides. The respondents in social studies are usually grouped into rather broad categories of noise exposure based on the extrapolation from either expected noise exposure or a few selected measurements. Although these gross estimates of exposure provide relatively good correlation with the grouped or mean-annoyance data, the true nature of the effects and interaction of factors such as the number and mix of aircraft as well as the influence of other noise sources are, in general, obscured.

Most of the past research (refs. 2 to 5) on annoyance of aircraft noise in the presence of other noise sources has treated the other noise strictly as a background which could possibly affect the subjects' judgments of the aircraft annoyance. Although references 2 and 3 agreed on the fact that increased background noise can decrease the annoyance, or more properly, noisiness of aircraft noise, they differed on the magnitude of the effect. The disagreement could have been the result of the small number of subjects used in both experiments but more probably was a result of the very different techniques of obtaining the response of the subjects. The results of reference 4, in which no effects of background noise were found, are of very doubtful validity because the testing methods and techniques were not sufficiently refined to distinguish the possible small effects of the different background types and the slightly differing levels used. In more recent work reported in reference 5, good agreement was found with the results of reference 2.

Although the laboratory studies are in general agreement, at least on the direction of the effect of background noise on annoyance, the situation found in some recent social surveys is more of a general disagreement. In two surveys of aircraft-noise annoyance which considered background noise (refs. 6 and 7), less aircraft annoyance was reported under conditions of heavy road-traffic noise than under conditions of light road-traffic noise. On the other hand, in two surveys of railroad-noise annoyance as pointed out in reference 8, the opposite effect was found. That is, greater annoyance due to railroad noise was found in areas with higher background-noise levels than in areas with lower background-noise levels.

In summary, references 2 to 8 have indicated a great need for information in several areas of community noise annoyance which involves exposure to more than one source of intrusive noise. In light of this need, two laboratory experiments, the results of which are reported herein, were conducted to determine the effects of road-traffic background noise on judgments of individual aircraft noises.

Part of the information presented in this report was included in a thesis entitled "Annoyance Due to the Interaction of Community Noise Sources" submitted by Clemans Ancelan Powell, Jr., in partial fulfillment of the requirements for the Degree of Doctor of Science in Acoustics, The George Washington University, Washington, D.C., May 1978.

SYMBOLS AND ABBREVIATIONS

More details of the indices and scales for acoustical measurements can be found in a number of general noise references, including reference 1.

ANSI American National Standards Institute

EPL effective perceived level, dB

EPNL	effective perceived noise level, dB
J	mean subjective response
L_A	A-weighted peak noise level, dB
L_a	ambient noise level, dB
L_{eq}	equivalent continuous sound level (energy averaged), dB
L_{NP}	noise pollution level, dB
L_1	level exceeded 1 percent of a time period, dB
L_{10}	level exceeded 10 percent of a time period, dB
L_{50}	level exceeded 50 percent of a time period, dB
L_{90}	level exceeded 90 percent of a time period, dB
L_{99}	level exceeded 99 percent of a time period, dB
PL	perceived level, dB
PNL	perceived noise level, dB
r	Pearson product-moment correlation coefficient
TCPNL	tone-corrected perceived noise level, dB
TNI	traffic-noise index, dB
σ	standard deviation of instantaneous noise level, dB

EXPERIMENTAL DESIGN

Test Facility

The interior effects room of the Langley aircraft noise reduction laboratory was used in all tests described herein. This room has been designed to simulate a typical living room and allow a controlled acoustical environment for subjective testing. The construction of the room is typical of modern single-family dwellings. Nominal dimensions are 4.9 m by 3.6 m by 2.4 m. The decor is typical of a modern living room as shown in figure 1. Loudspeaker systems are located outside the room to provide a realistic simulation of residential environmental noise. Further details of the construction, acoustical reproduction systems, and acoustical response of the test room are given in apppendix A.

Noise Stimuli

Airplane-noise stimuli.- In the two tests described herein the same set of airplane-noise stimuli was used. The differences between the individual tests were solely a result of presenting these noises at different levels and at different periods between flyovers. Four different airplane types were used. One recorded approach noise of each type was selected from a library of recordings as being representative of the airplane type and as having the best signal-to-noise ratio. Details of the recording and processing procedures and acoustical analyses of these noises are given in appendix B. The noise levels for the airplane-noise stimuli for the two experiments are given in table I.

Traffic-noise stimuli.- The same set of road-traffic noises was used in both tests described herein. This set consisted of three different types of traffic noise, distinguishable by the standard deviation in noise level over periods ranging from 9 to 30 min. These noise types have been classified as standard deviations that are low (σ = 1.3 dB), medium (σ = 3.6 dB), and high (σ = 4.1 dB) and are all representative of freely flowing high-speed road traffic. Details of the recording and processing procedures and acoustical analyses of these noises are also given in appendix B. The equivalent continuous sound levels L_{eq} used in the first experiment were nominally 33 dB, 43 dB, and 53 dB for each noise type. For the second experiment only the high and low standard-deviation noise types were used. The nominal L_{eq} levels used were 34 dB, 41 dB, 48 dB, and 55 dB.

Experimental Design

First experiment.- The experimental design was an incomplete block, factorial design with repeated measures. The factors consisted of 16 airplane-noise stimuli, 3 traffic-noise types, and 3 traffic-noise levels. Additional details of the design are given in appendix C. A total of 27 subjects judged each airplane stimuli presented in sessions of 30-min duration with 3 of the 9 possible traffic-noise conditions. During a second visit to the laboratory, 1 week after the first visit, each subject judged a complete replicate of the stimuli judged in this first visit.

Second experiment.- One of the main purposes for the second experiment was to examine possible interaction effects between traffic-noise type and traffic-noise level. Therefore, a design was needed in which there was no confounding between these factors or their interaction and any other factor in the design. The design that was selected was a complete factorial design with repeated measures. The factors consisted of the 16 airplane-noise stimuli, 2 traffic-noise types, and 4 traffic-noise levels.

For this experiment, it was necessary to reduce the time required for each session which consisted of one of the eight possible combinations of traffic-noise level and traffic-noise type, so that all of the combinations could be given to each subject group. To accomplish this, the 16 airplane-noise stimuli were recorded in the same manner as for the previous experiment except that the interstimuli time between flyovers was reduced from a range of 55 to 85 sec to 5 sec. This reduced the total session time to approximately 10 min. Details of this design are also given in appendix C.

Subjective Evaluations

Judgments of annoyance in both experiments were made on a numerical category scale of "0 to 9," the end points of which were labeled "Not Annoying At All" and "Extremely Annoying." Copies of the instructions and the scoring sheet are given in appendix D.

Subjects

The subjects who were used in both experiments were supplied to the National Aeronautics and Space Administration under contract. These subjects were drawn from the general population of the cities of Hampton and Newport News and from York County in Virginia. Approximately one-half of the subjects were affiliated with various civic organizations with the result that payment for their services went to the organizations. The remainder were paid directly for their services. All subjects were given audiograms prior to testing to ensure normal hearing abilities (ANSI 1969). A total of 27 subjects were used in the first experiment; 24 were used in the second experiment.

RESULTS AND DISCUSSION

First Experiment

The primary analysis for this experiment was the analysis of variance given in table II. The basic design for the analysis is patterned after one described in reference 9 for a 3 × 3 factorial experiment with blocks of three conditions each. The primary divergence from the referenced analysis was the inclusion of an additional factor (airplane-noise stimuli) and the exclusion of one replication. Because of the exclusion of the replication, the estimate of block differences was completely confounded with that of the quadratic interaction of traffic-noise level and traffic-noise type.

A significant effect (at the 1-percent level) was found for repeats, although in terms of the average (over subjects) judgment this effect amounted to only a 0.27 increase from the first occasion to the repeat occasion (4.52 to 4.79). For the analysis of variance, the airplane type and level conditions were considered to be 16 distinct stimuli because the levels were not consistent across airplane type. The airplane-stimuli effect was found to be significant as would be expected.

The main effects of traffic-noise level and traffic-noise type were both found to be significant at the 1-percent level. However, no significance was found in interactions between the airplane-noise stimuli and traffic-noise level or between the airplane-noise stimuli and traffic-noise type. The linear interaction term between traffic-noise type and level was found to be significant at the 1-percent level. The following sections will examine, in more detail, some of the more important of these findings.

Effects of airplane-noise stimuli.- The main differences between the judgments for the different airplane-noise stimuli are shown in figure 2. In this figure the mean subjective response (mean of judgments over subject, repeats, traffic-noise types, and traffic-noise levels) for each airplane type and level is shown as a function of the airplane peak noise level in L_A. Some consistent differences can be seen between the results for the different airplane types. Separate regression analyses for each airplane type indicated that these differences were primarily due to differences in the intercept value for the regression analysis rather than to a difference in slope. Such differences are usually a result of an inability of the noise rating scale (in this case L_A) to account properly for some characteristics of the individual noises, such as duration or tonal quality. In general, it was felt, however, that the differences between the airplane-noise stimuli were explained sufficiently by the peak level. Linear least-squares regression of the mean response on the peak level yielded a product moment correlation coefficient of 0.984, which indicates that nearly 97 percent of the variation in mean response was explained by peak-level differences. The slope of the regression indicates that a one-unit difference in mean subjective response was very nearly equivalent to a 4-dB change in level.

Similar regressions of mean subjective response on levels measured in other units, such as perceived noise level (PNL), resulted in correlations which were significantly different from those for L_A. Because of the good correlation of the airplane-noise mean response with L_A and because of its use in most major indices for the prediction of human response, it was decided that all acoustical analyses for the remaining experiments would be performed solely in terms of L_A.

Effects of traffic noise on airplane judgments.- The effects of traffic-noise level on judgments of individual airplane-noise annoyance are shown in figure 3(a). The mean subjective response (over subjects, repeats, airplane-noise stimuli, and traffic-noise types) is plotted as a function of traffic background noise level in terms of the A-weighted equivalent continuous sound level L_{eq}. A consistent decreasing trend of response was found for increasing traffic-noise levels. That is, the subjects, in general, reported that their annoyance to the airplane noises was less under the condition of high traffic-noise level than under low traffic-noise level. The increase in traffic-noise level of 20 dB (L_{eq} = 33 to 53 dB) resulted in a decrease in mean subjective response of 0.65 unit. By using the results of the regression of mean subjective response on airplane-noise level, the 0.65-unit decrease can be equated to an equivalent reduction of 2.7 dB in airplane-noise level.

The effects of traffic-noise type on the airplane-noise judgments are shown in figure 3(b). The mean subjective response is shown for the conditions of low, medium, and high standard deviation in traffic-noise level. A generally consistent trend was found in that the mean subjective response decreased with increased standard deviation. However, in terms of the standard deviation in dB units, the trend did not appear linear. An increase from low to high standard deviation resulted in a reduction of 0.41 unit of subjective response, or an equivalent reduction of 1.7 dB in airplane-noise level.

Because of the confounding which existed in the experimental design between block effects and quadratic interactive effects of traffic level and type, a somewhat cloudy picture remained concerning the true nature of the interactive effects of traffic level and type. Figure 4 shows the mean subjective response as a function of traffic-noise level with the three traffic-noise types as a parameter. Although the linear interaction was found to be significant from the analysis of variance, the sum of squares resulting from block or quadratic interaction was so great that the linear effect is completely obscured in the figure.

One aspect of this experiment which perhaps influenced the results in either a systematic or random way was the long interstimuli period. Numerous subjects expressed boredom between the airplane flyovers during which time they were not occupied in any way. Because of this possible source of error and because of the confounding which existed in the experimental design, an additional experiment which eliminated both of these problems was planned and conducted to examine further the effects of traffic noise and type on annoyance of individual airplane flyover noises.

Second Experiment

The primary analysis for this experiment was the analysis of variance given in table III. The basic design for the analysis is patterned after one described in reference 9. The factors of airplane levels, traffic levels, and traffic types were considered to be fixed, whereas the subject factor was considered to be random. The analysis of table III does not consider the repeat conditions. It was found that a significant difference existed between the repeat conditions, i.e., the judgments made in the subjects' second session and those made in the final session. Since the order of presentation was counterbalanced and since the inclusion of the last session data would create an unnecessary partial confounding of main effects with groups of subjects, it was decided that the benefits of excluding these judgments from the analysis was greater than the benefit of increased number of judgments per cell.

As can be seen from table III, the airplane level effect dominated the judgments. The traffic-noise level was also found to be significant (at the 1-percent level). However, the traffic type, or standard deviation in level, was not found to be significant. The only interaction term found significant was between airplane level and traffic level.

The following sections will examine in more detail these significant effects and some of the differences in results between the first and second experiments.

Effects of airplane-noise stimuli.- As was found in the first experiment, the differences between the airplane-noise levels were clearly the dominant source of variance in the airplane judgments. The mean subjective response (over traffic type and level and over subjects) is shown in figure 5 as a function of the airplane-noise-stimuli peak level in L_A. A close comparison of this figure with similar results from the previous experiment (fig. 2) reveals a remarkable similarity between the two experiments. The slopes and intercepts obtained for the two experiments were extremely consistent. More important, however, is the consistency both within and between airplane types between the two experiments. Although there was some variation in the stimuli levels between the two experiments in which slightly different testing techniques and different groups of subjects were used, the differences between the different airplane types remained. Even though these results are important to the present studies from the standpoint of reliability, an importance to the field of subjective acoustic testing is also implied. This implication is that, based on mean results, subjects in carefully planned and conducted experiments are capable of making reliable judgments and detecting very subtle differences between noise sources.

Effects of traffic noise on airplane judgments.- The general effects of traffic-noise level on judgments on individual airplane-noise annoyance are depicted in figure 6. The mean subjective response (over subjects and airplane-noise stimuli) is plotted as a function of traffic-background-noise level in A-weighted L_{eq}. Data points are shown for both traffic types and the single linear-regression equation is plotted. Variation for the two types about the regression line appears, in general, to be random as was found in the analysis of variance in table III. That is, no significant effect of traffic type was found. A consistent decrease in response was found for increasing traffic-noise levels. An increase in traffic level from L_{eq} = 34 to 55 dB resulted in a decrease in mean subjective response of 0.77 unit. By using the results of the regression of mean subjective response on airplane-noise level, the 0.77-unit decrease can be equated to an effective reduction of 3.1 dB in airplane noise.

Effects of interaction between airplane level and traffic level.- The analysis of variance (table III) indicated a significant interaction of airplane level and traffic level. To examine this interaction in more detail, separate regressions were performed for each traffic level of the mean annoyance response on airplane-noise level. The results of these regressions are presented in table IV. It was expected that for a constant background level the lower airplane-noise levels would be subject to a greater reduction in annoyance than would the higher levels. It was also expected that the reduction would become greater as the background level approached the airplane-noise level. Therefore, for increasing background level the regressions should indicate a decrease in intercept and an increase in slope. As can be seen in table IV these trends were found except for the highest traffic level. An increase in traffic level from L_{eq} = 48 to 55 dB resulted in an increase in intercept and a decrease in slope, although there was a consistent decrease in mean value.

A more detailed reason for this inconsistency is depicted in table V, which presents the mean annoyance response for each of the airplane-noise stimuli at each traffic-background-noise level. The order of the airplane stimuli is based on increasing response at the lowest traffic-noise level. For those cases in which the response was less than 3.5 at the lowest traffic level, there was an increase in response as the traffic level was increased from L_{eq} = 48 to 55 dB. Although this behavior could be just a result of the random nature of subjective data, the consistency for these particular four airplane-noise stimuli tends to confirm a general trend. In order to gain a somewhat better insight into the nature of the interaction between airplane stimuli and traffic level, the mean response data from table V were grouped in the following manner.

The first group contained those stimuli for which the mean response at the lowest traffic level was less than 3.50; the second group, between 3.50 and 5.25; the third group, between 5.25 and 7.00; and the fourth group, greater than 7.00. The mean response was obtained over each group for each traffic-noise level. These data are presented in figure 7. From this figure a rather consistent trend emerges for the slope of the line segments connecting the data points for constant airplane noise. This trend indicates that the magnitude of the slope was greatest when the airplane and traffic level differed by 20 to 30 dB. The magnitude of the slope was least when the airplane-noise level greatly exceeded the traffic level and also when the airplane-noise level exceeded the traffic level by only 7 to 13 dB. When the traffic level became nearly equal to the airplane level there was an increase in annoyance response for an increase in traffic level. To see this general trend more clearly, the data of figure 7 have been normalized and replotted in figure 8. The data represented by the solid symbols in figure 7 were each representative of a difference of 24 to 26 dB between the airplane peak noise level and the traffic L_{eq} level. The data for the remaining traffic levels within each airplane-noise level were subtracted from the data represented by the solid symbols to give a relative response within each airplane-noise condition. The difference between the extreme responses of the 81.1-dB airplane-noise condition was subtracted in turn from each of the relative responses. The values thus obtained were plotted in figure 8 as the reduction in mean subjective response as a function of the difference between the peak airplane-noise level and the traffic L_{eq} level. The maximum reduction in response occurred for differences in airplane-noise level and traffic-noise level of approximately 10 dB. It should be pointed out that this normalization procedure resulted in a compounding of the errors associated with each data point and is, therefore, used only to illustrate the general trend and consistency of the data across the wide range of airplane-noise levels.

Comparison of the Two Experiments

As was mentioned previously, the effects due to airplane-noise level and airplane types were very similar for both experiments. This was clearly demonstrated by comparing figure 2 with figure 5. The effects of the traffic noise of the two experiments on the judgments of airplane noise were, however, a mixture of consistencies and inconsistencies. These will be the topics of further discussion in this section.

Effects of traffic-noise level.- Traffic-noise level was found to be a significant factor in the analyses of variance for both experiments. (See tables II and III.) In both experiments an increase in traffic level produced a decrease in airplane annoyance. Figure 9 depicts the effect of traffic level for both experiments. The data points represent the mean of the judgments over airplane noises, traffic-noise types, and subjects. As can be seen, very similar effects were exhibited in both experiments. The very small differences in slopes could not be found significant and indicate that in both experiments the direction and magnitude of changes in airplane-noise annoyance associated with changes in traffic-background-noise level were, in general, very consistent.

Effects of traffic-noise type.- In contrast to the consistency of results for traffic-noise levels between the two experiments, a great inconsistency was found for traffic-noise types. In the first experiment a significant effect of traffic-noise type was found (table II), whereas in the second experiment no significant effect could be attributed to traffic-noise type (table III). Also, in the first experiment a significant interaction was found between traffic level and traffic type, whereas the interaction was not found significant in the second experiment. It should be remembered that the experimental design of the first experiment was somewhat undesirable from the standpoint of the partial confounding of subject groups with the interaction of traffic level and traffic type. Whether or not this could have been the reason for the inconsistency between the experiments can only be left to supposition at the present time. It must be concluded that since the experimental design for the second experiment was clearly superior to that of the first from the standpoint of completeness and balance, the results of the second experiment should likewise be of greater validity.

Comparison of Results With Earlier Studies

In a previous study (ref. 5) subjects judged a somewhat limited set of airplane noises in the presence of traffic noise in a more sterile laboratory environment than that used in the two present studies. In this previous study it was found that a measurable and consistent reduction in judgments of individual airplane noise was produced by increased traffic-noise levels. Several possible criticisms of this study were that the environment was an anechoic chamber which afforded very little realism to a home situation, and that the subjects were a somewhat select group of graduate students and university staff actively working in various fields associated with acoustics. As a consequence, one of the primary goals of the present experiments was to investigate whether similar results would be obtained in a more realistic environment, such as the living-room setting, and with subjects drawn from a more diversified population. As has been shown in the previous sections, a measurable and generally consistent reduction in airplane judgments was produced by increased traffic levels in the two present experiments.

In the previous study (ref. 5) it was found from linear multiple-regression analyses that the judgments J on a numerical category scale were proportional to the following relationship of the airplane and traffic-noise levels:

$$J \cong (L_A - 0.313L_a)$$

where L_a was the ambient or traffic-noise level and L_A was the peak airplane-noise level. However, for the first of the present studies it was found that

$$J \cong (L_A - 0.142L_a)$$

and for the second of the present studies,

$$J \cong (L_A - 0.144L_a)$$

There was an obvious disagreement by a factor of two in the relative magnitude of the effect of the traffic background level on the judged annoyance of the airplane noises between the previous study and the two present studies.

One reason for this disagreement is that the range of differences in level between the airplane noises and traffic noises was greater in the present studies than in the previous study. When the airplane levels were much greater than the traffic levels, very little reduction in annoyance was reported; therefore, the slope of a linear regression would expectedly be lessened. In the previous experiment the reversal of the trend for decreased annoyance as the traffic-noise level approached the level of airplane noise was not found. Whether this was due to environment (anechoic chamber), the use of trained subjects, a different noise set, or some other factor cannot be determined. However, whatever the cause, this difference in results would explain the difference in relative magnitude (slope) between the previous and present experiments.

The absolute magnitude of effects of traffic noise on airplane annoyance was extremely consistent between the previous and present experiments. From figure 8 it can be seen that the greatest reduction was approximately 1.2 subjective units. Based on the regression results shown in figure 5 (slope, 0.25 subjective unit per dB), this reduction in annoyance was the equivalent of a 5-dB reduction in airplane-noise level. The reduction found in the previous experiment was 4.9 dB.

CONCLUSIONS

Two laboratory experiments were conducted to examine the effects of road-traffic background noise on judgments of annoyance (or more accurately, noisiness) of individual airplane flyover noises. In both experiments a set of 16 airplane flyovers (4 airplane types, 4 noise levels each) were judged in the presence of the different traffic noises. The traffic noises in the first experiment consisted of three traffic types at three noise levels each. The traffic noises in the second experiment consisted of two traffic types at four noise levels each. In the first experiment the period between airplane flyovers varied between 55 sec and 85 sec. In the second experiment the period between airplane flyovers was 5 sec. The following conclusions were noted:

1. The airplane noises were judged less annoying in the presence of high traffic-noise levels than in the presence of low traffic-noise levels.

2. The magnitude of the effect of traffic-noise level, a maximum reduction in airplane-noise annoyance equivalent to a 5-dB reduction in airplane-noise level, was consistent between the two experiments and with a previous experiment.

3. A significant interaction was found between airplane-noise level and traffic-noise level. The greatest reduction in airplane annoyance occurred when the peak airplane-noise level was approximately 10 dB greater than the traffic-noise level.

4. The consistency of mean response between the two experiments for each of the airplane types and noise levels is indicative of the reliability and discriminability possible in controlled subjective experiments.

5. Comparison of the results of this study, conducted in a realistic environment, with previous studies, conducted in a more sterile laboratory environment, indicated a very similar maximum reduction in airplane annoyance because of a traffic-noise background.

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APPENDIX A

TEST FACILITY

Test Area

The interior effects room of the Langley aircraft noise reduction laboratory was used in all tests described herein. This room has been designed to simulate a typical living room and allow a controlled acoustical environment for subjective testing. As shown in figure A1, the interior effects room is contained within a larger room 8.3 m long and 7.1 m wide. The outer room is designed to provide isolation from external-noise sources and to prevent noise generated within the area from interfering with research conducted in other areas of the laboratory. The test room is suspended from the ceiling of the outer room over an open basement area to provide seismic isolation and to allow vibratory inputs for other types of subjective testing.

The construction of the test room is typical of modern single-family dwellings. Wall studs and floor and ceiling joists are of wood and are of similar size and spacing as those required by most building codes. The interior walls are made of gypsum board in the usual dry-wall manner; doors and windows are stock residential items; the decor is typical of a modern living room.

The loudspeaker systems used to produce the airplane and road-traffic noise stimuli were located outside the test room to provide a more realistic simulation of residential environmental noise. The locations of the loudspeaker systems are indicated in figure A1 by the dashed-line rectangular areas. Loudspeaker systems 1 to 4 were mounted above the ceiling of the test room and were used to reproduce the airplane-noise stimuli. Loudspeaker systems 5 and 6, which were used to reproduce the traffic-noise stimuli, were mounted at window height approximately 2 m across an open area to the basement from the test room.

Acoustical Response in Test Area

The following measurements were made to determine if the acoustical environment inside the test area was sufficiently similar to that in a typical residence. A "pink noise" source was connected to the inputs of the amplifiers which powered loudspeaker systems 1 to 4. One-third-octave-band analyses were performed for each of the subject seat locations. The 1/3-octave-band frequency response for the subject locations to the overhead or airplane-noise reproduction system is shown in figure A2. For each frequency band the range of response over all locations is represented by the shaded area. These values have been normalized at 63 Hz for comparison with data from reference 10. The three data lines represent the transmission of airplane noise in octave bands from a large set of measurements in typical homes in various parts of the United States. With a few exceptions the measurements in the test room fall within the range of typical residences.

In the same manner measurements were made of the response in the test room to pink noise from the loudspeaker systems used to produce the traffic-noise stimuli. The results of these measurements are shown in figure A3. Again, the range of 1/3-octave-band response at the subject locations is represented by the shaded area at each center frequency.

The results of both sets of measurements of the response in the test area to pink noise indicated that the acoustic simulation afforded by the test facility and audio reproduction system was sufficient without the need for artificially altering the spectra of the noise stimuli. The ambient noise level in the test area, approximately 20 dB, was lower than could be expected in typical residences and was sufficiently low so that, in all experimental cases to be described, the audible background noise level was set by the intended noise stimuli.

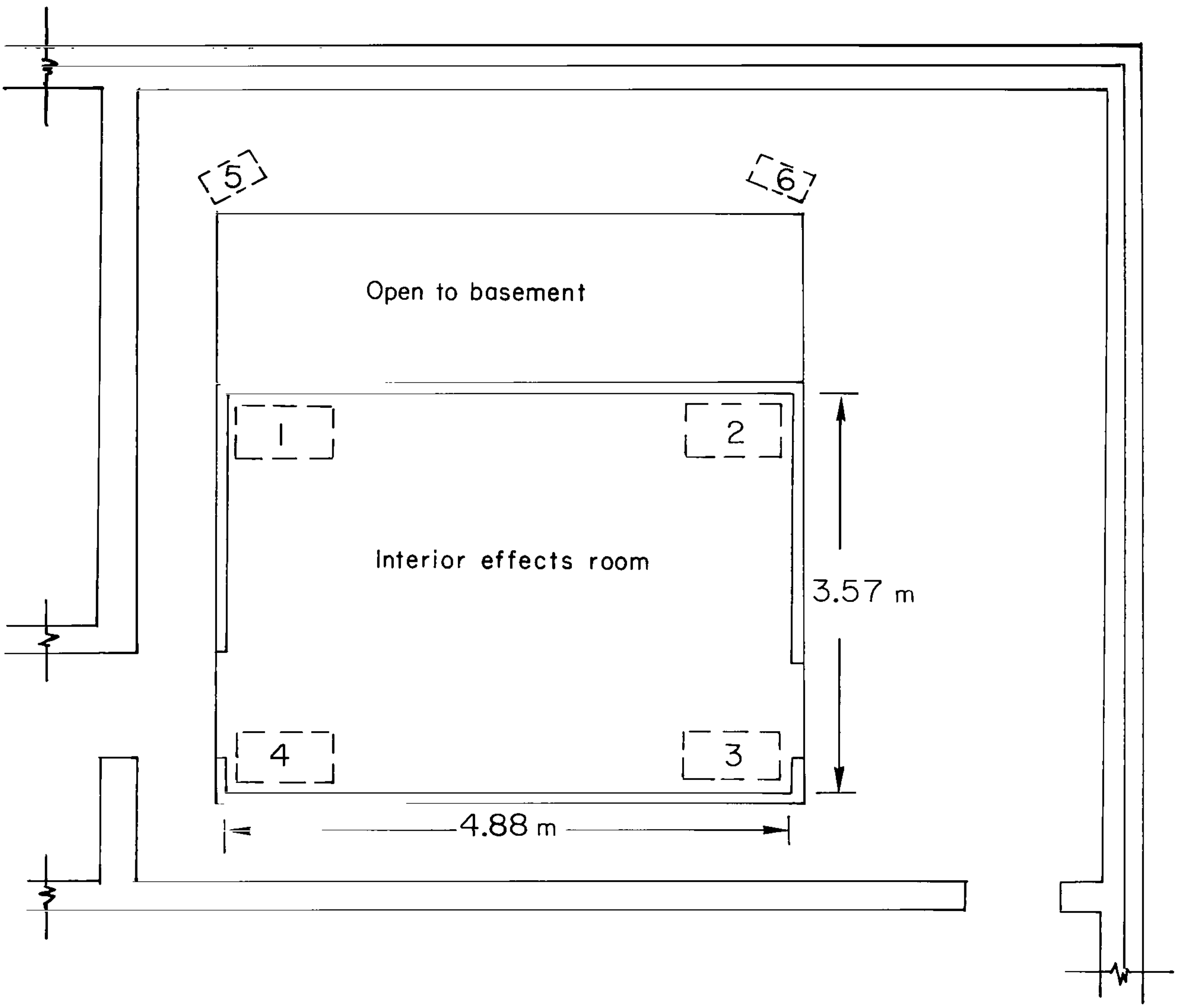


Figure A1.- Floor plan of test facility.

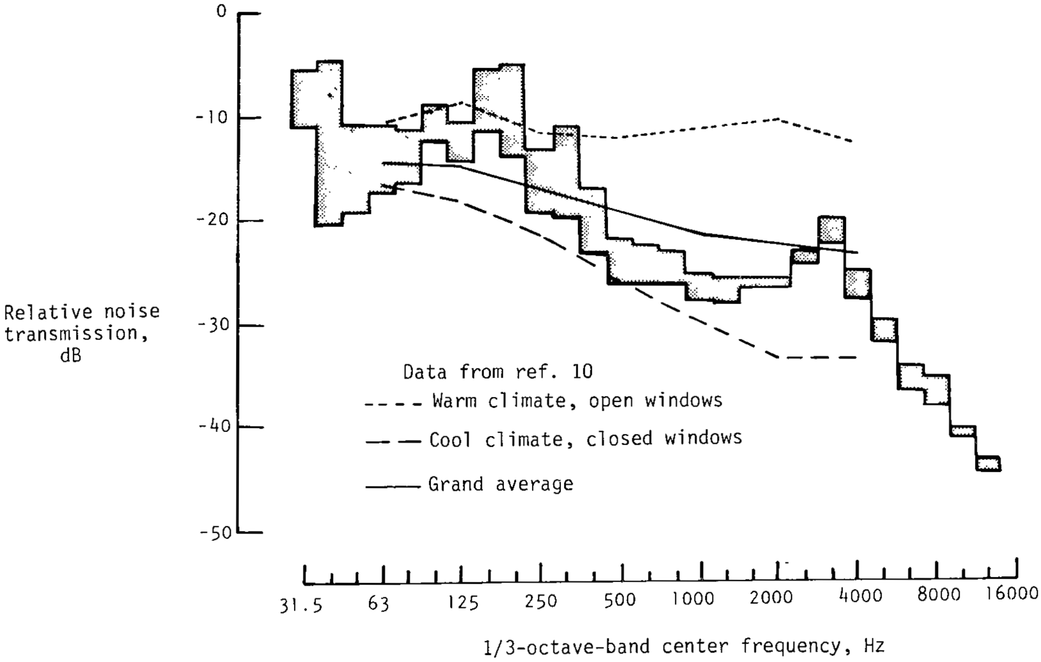


Figure A2.- Transmission characteristics of test facility for airplane-noise stimuli.

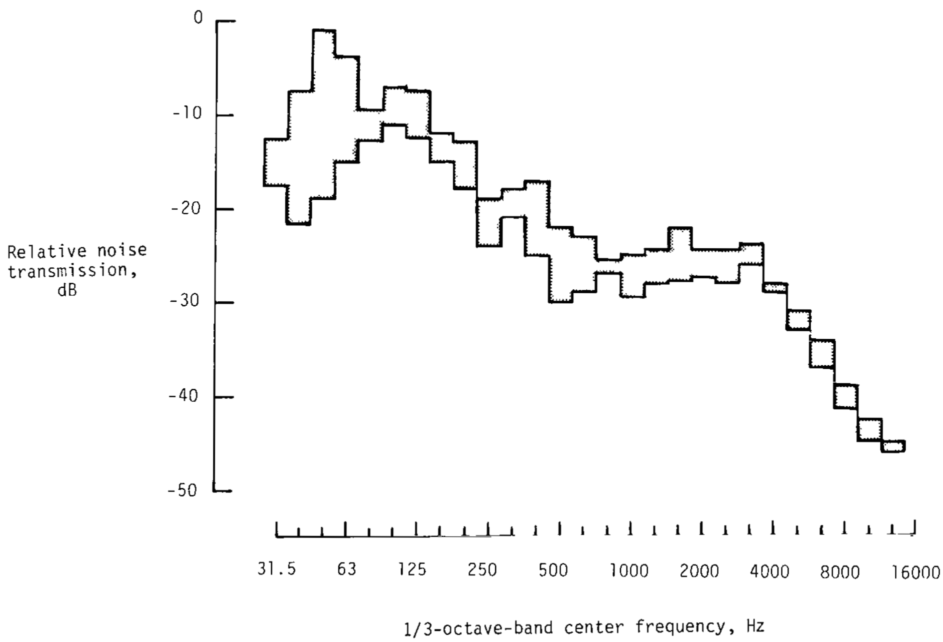


Figure A3.- Transmission characteristics of test facility for traffic-noise stimuli.

APPENDIX B

NOISE STIMULI

Airplane-Noise Stimuli

In the two tests to be described the same set of airplane-noise stimuli were used. The differences between the individual tests were solely a result of presenting these noises at different levels and at different periods between flyovers. Four different airplane types were used. One recorded approach noise of each was selected from a library of recordings as being representative of the airplane type and as having the best signal-to-noise ratio. The four types were the 747, 707, DC-10, and 727. Each of these airplanes had turbofan engines with various bypass ratios and represent a wide range of gross weights. The noise of each type is characterized by a high-frequency fan noise of distinct tonal quality. This characteristic was deliberately chosen for the tests to be described in an effort to reduce confusion among the test subjects between the sources of the noise stimuli. All of the recordings were made at a location approximately 1400 m from touchdown directly under flight paths at Dulles International Airport.

The original monophonic recordings for each airplane type were rerecorded to simulate motion and directionality for a pseudo stereophonic effect in the room. This was acocmplished by manually fading the monophonic signal into two channels to provide the correct time history of amplitude. When reproduced in the test facility, the noises appeared to fly over the listener in a realistic manner.

Table BI gives some selected acoustical analyses of the airplane-noise stimuli as recorded on the presentation tapes for the first experiment to be described. These values are presented only to point out the relative differences between several different scales for quantifying airplane noise. The actual levels presented to the test subjects for each experiment are given in the main report. As pointed out earlier each airplane noise had distinct tonal qualities. Corrections for these tones ranged from 0.7 dB to 3.1 dB over the airplane types. Since the recordings were made for approach conditions close to the touchdown point, the noises were quite short in duration as evidenced by negative duration corrections between 6.6 dB and 8.7 dB.

Time histories of these noises are shown in figure B1 in terms of the A-weighted noise level. As shown, the duration at 10 dB down from peak was very short, typically 4 to 5 sec. The dynamic range for each of the noises was at least 40 dB.

Traffic-Noise Stimuli

The same set of road-traffic noises was used in all the tests to be described. This set consisted of three different types of traffic noise, distinguishable by the standard deviation in noise level over periods ranging from 9 to 30 min. These noises have been classified as standard deviations that are low (σ = 1.3 dB), medium (σ = 3.6 dB), and high (σ = 4.1 dB) and are all representative of freely flowing high-speed road traffic. The stereophonic recordings were made by using the coincident directional microphone technique.

The low standard-deviation condition was recorded at a location approximately 200 m from the near lane of a limited-access, four-lane, divided highway at a near peak-flow condition. For presentation to the test subjects, this recording was copied and then repeatedly mixed with its copies until the traffic-flow rate simulated a condition eight times that of the original recording. During each rerecording process the start times of the recordings were staggered so that a given noise event was not overlayed with the same event of another recording. The final product of this process was a recording in which single events could rarely be distinguished. An A-weighted time history of a segment of this recording is shown in figure B2(a).

The medium standard-deviation condition was recorded at a location approximately 100 m from the near lane of the same section of limited-access highway during a period of less traffic flow. A segment of the time history of this recording is shown in figure B2(b). In this case, truck-traffic events were clearly distinguishable and automobile events were usually distinguishable.

The high standard-deviation condition was recorded at a distance of approximately 20 m from a different section of the same highway during a period of even less traffic flow. From the time-history segment presented in figure B2(c) it can be seen that individual traffic events are clearly distinguishable.

Some selected acoustic analyses for the tape recordings used in the subjective tests are given in table BII. All of the values given are in terms of A-weighted dB levels. The equivalent continuous sound level L_{eq} was artificially set at approximately 53 dB for each of the test recordings. The primary purpose of this table is to illustrate the differences between the various measures and L_{eq} for each traffic-noise condition.

TABLE BI.- SELECTED ACOUSTICAL ANALYSES OF AIRPLANE-NOISE STIMULI

Airplane type	L_A, dB	PNL, dB	TCPNL, dB	EPNL, dB	PL, dB	EPL, dB
747	98.8	114.0	115.2	106.5	105.7	96.5
707	104.8	119.8	122.9	116.3	110.7	104.3
DC-10	89.8	107.3	109.0	100.8	98.0	90.1
727	97.5	112.8	113.5	106.5	103.4	95.7

TABLE BII.- SELECTED ACOUSTICAL ANALYSES OF TRAFFIC-NOISE STIMULI

Standard deviation	L_{eq}, dB	L_{NP}, dB	TNI, dB	σ, dB	L_{99}, dB	L_{90}, dB	L_{50}, dB	L_{10}, dB	L_1, dB
Low	52.9	56.2	36.1	1.29	50.0	51.4	52.7	55.1	56.3
Medium	53.1	62.2	53.8	3.57	45.1	47.1	50.8	56.3	61.7
High	53.0	63.5	54.9	4.09	42.7	46.2	49.8	55.8	62.7

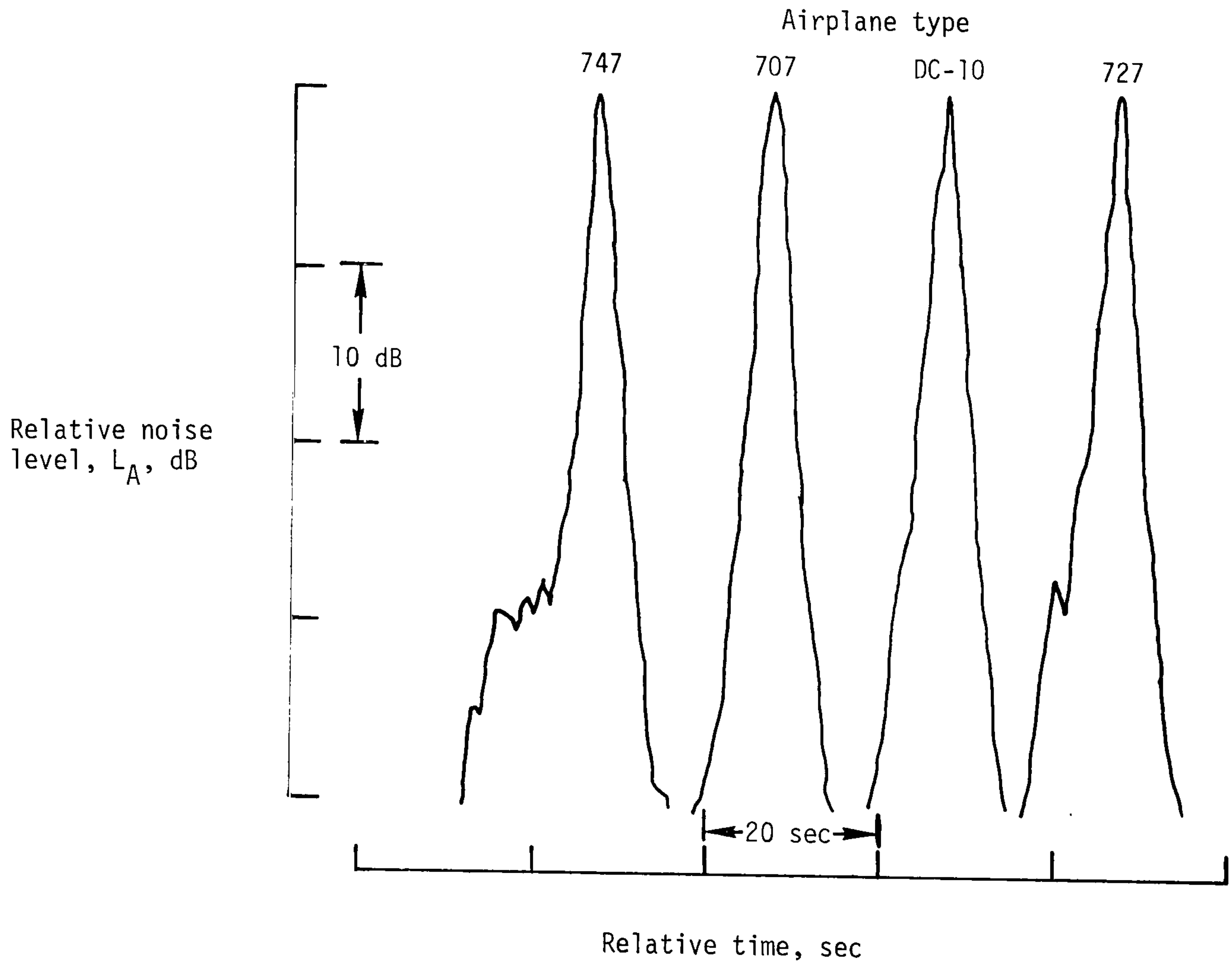
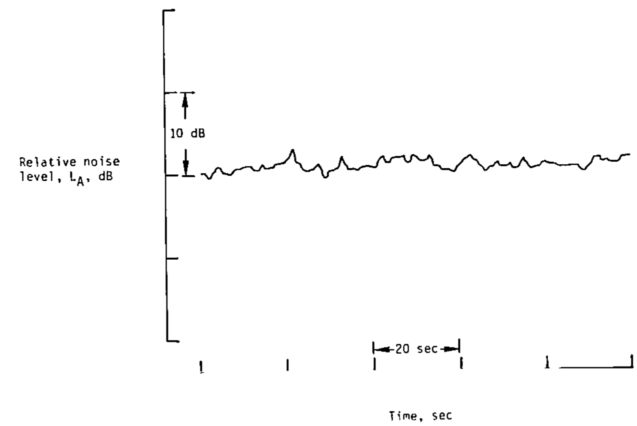
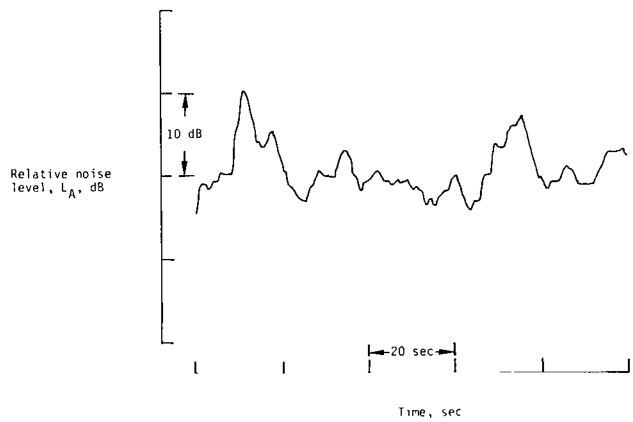


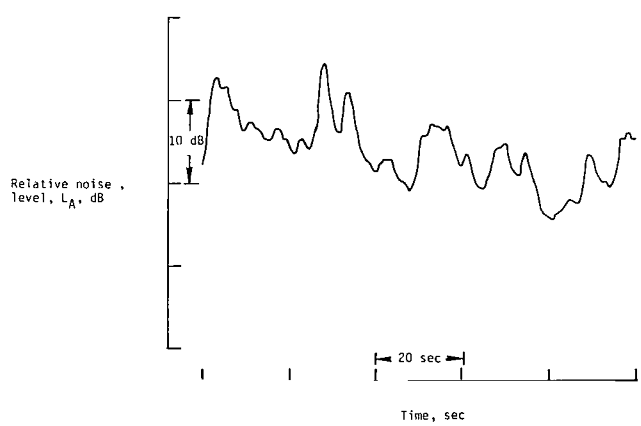
Figure B1.- Time histories of airplane-noise stimuli.



(a) Low standard deviation. σ = 1.3 dB.



(b) Medium standard deviation. σ = 3.6 dB.



(c) High standard deviation. σ = 4.1 dB.

Figure B2.- Time histories of traffic noise at low, medium, and high standard deviation.

APPENDIX C

EXPERIMENTAL DESIGN

First Experiment

The primary goal of the experimental design for this experiment was to provide a set of test conditions in which subjects could judge individual airplane-flyover noises in a variety of road-traffic background noises. An additional stipulation was that the same basic conditions would later be replicated for subjects to make judgments on sessions or simulated environments of extended periods containing a multitude of airplane and traffic-noise events. Some constraints were also required to prevent subject boredom and fatigue. These included a limit of approximately 2-1/2 hours of total testing time on a given day and that breaks should be given at least every half hour. The final design selected was an incomplete block, factorial design with repeated measures. The factors consisted of 16 airplane-noise stimuli, 3 traffic-noise types, and 3 traffic-noise levels.

Although the 16 airplane-noise stimuli consisted of 4 different airplane types, with each presented at 4 sound pressure levels, these were not considered as a 4 × 4 factorial design. The levels were not consistent across airplane type; rather, they were each presented at a set of levels representative of the airplane type. Each of the 16 airplane-noise stimuli were recorded on 2 tracks of 9 presentation tapes in 3 different orders. These orders are given in table CI. The order for each tape was established by first assigning orders to the airplane types which were successive rows of a balanced 4 × 4 Latin square. (See ref. 9.) The levels were then assigned at random with a constraint that not more than two similar levels would occur in succession. The time between flyovers on the tapes was varied between 55 sec and 85 sec, and the total time for each tape was 30 min.

The three different traffic types were similarly recorded on the same nine tapes by using the two remaining tracks so that each tape contained one of the nine possible combinations of airplane order and traffic types. The three traffic-noise levels were established during playback to the subjects by controlling the gain of the reproduction system.

The subjects were given prescribed combinations of airplane-noise order, traffic-noise type, and traffic-noise levels as shown in table CII. The subjects were randomly assigned to nine groups of three subjects. Each group was given three of the combinations on each of two occasions or visits to the laboratory. The combinations given on the second occasion were the same as on the first occasion but in reversed order. It can be seen from table CII that subject groups 1, 2, and 3 were given the same traffic type and level conditions; however, these were given in combinations of different airplane-stimuli order and in different presentation order. The presentations to groups 4, 5, and 6 and to groups 7, 8, and 9 were similarly arranged. The combinations prescribed for these major or combined groups were considered as blocks in the analysis of results. Because of the particular combinations within the blocks the quadratic interaction effects between traffic level and type were confounded with block effects (ref. 9). Although such confounding was not really desirable, this procedure was considered preferable to other confounding procedures.

Second Experiment

One of the main purposes for this second experiment was to examine possible interaction effects between traffic-noise type and traffic-noise level. Therefore, a design was needed in which there was no confounding between these factors or their interaction and any other factor in the design. It was also necessary that the design satisfy the time constraints for testing as mentioned in the previous section. The design that was selected was a complete factorial design with repeated measures. The factors consisted of the 16 airplane-noise stimuli, 2 traffic-noise types, and 4 traffic-noise levels.

For this experiment, it was necessary to reduce the time required for each session which consisted of one of the eight possible combinations of traffic-noise level and traffic-noise type, so that all of the combinations could be given to each subject group. To accomplish this, the 16 airplane-noise stimuli were recorded on 2 tracks of 6 presentation tapes in 3 different orders in the same manner as they were for the previous experiment except that the interstimuli time between flyovers was reduced to 5 sec. This reduced the total session time to approximately 10 min. The order of the airplane-noise stimuli on the presentation tape recordings was identical to the orders used in the first experiment. During the rerecording process some slight level changes occurred.

The two different types of traffic noise (σ = 1.3 and 4.1 dB) were similarly recorded on the six presentation tapes by using the remaining two tracks so that each tape contained one of six possible combinations of airplane order and traffic type. The four traffic-noise levels were established during playback to the subjects by controlling the gain of the reproduction system.

The subjects were given prescribed orders of the combinations of airplane-noise order, traffic type, and traffic-noise level as shown in table CIII. The subjects were randomly assigned to eight groups of three subjects. Each group was given a total of nine sessions or combinations of airplane order, traffic level, and traffic type.

Because of the fact that each of the airplane noise stimuli were contained in each session, the order of the stimuli within sessions was not very critical. The reasons for different orders was to provide variety and to prevent the subjects from recognizing a pattern to the order of airplanes. For this reason the order of the airplanes was simply assigned to the session presentation order by the sequence 1, 2, 3, 2, 3, 1, 3, 1, 2 for all subject groups.

The orders of the combination of traffic level and traffic type for each group were, however, somewhat critical. These orders were established as follows: Each of the eight combinations of type and level was randomly assigned to the numerals 1 to 8. A balanced 8 × 8 Latin square was formed of these combinations. The ninth combination or session for each group was identical to the second session.

APPENDIX C

TABLE CI.- PRESENTATION ORDERS FOR AIRPLANE-NOISE STIMULI

Order 1	Order 2	Order 3
Aγ	Dδ	Bδ
Bα	Cα	Dγ
Dβ	Aβ	Aα
Cδ	Bγ	Cβ
Bγ	Aγ	Dα
Cα	Dβ	Bβ
Aβ	Bδ	Cδ
Dγ	Cδ	Aγ
Cβ	Bα	Cγ
Dδ	Aα	Aδ
Bβ	Cβ	Bα
Aδ	Dγ	Dβ
Dα	Cγ	Aβ
Aα	Bβ	Cα
Cγ	Dα	Dδ
Bδ	Aδ	Bγ

Stimuli key				
Presentation level, L_A, dB	Airplane type			
	A (747)	B (707)	C (DC-10)	D (727)
α	62.1	65.3	55.3	65.6
β	69.3	71.6	60.6	70.2
γ	76.3	77.3	67.1	77.0
δ	83.3	83.9	74.5	84.4

TABLE CII.- PRESENTATION ORDER FOR FIRST EXPERIMENT

Block	Subject group	First visit			Second visit		
1	1	111	222	333	333	222	111
	2	122	233	311	311	233	122
	3	133	211	322	322	211	133
2	4	332	113	221	221	113	332
	5	313	121	232	232	121	313
	6	321	132	213	213	132	321
3	7	223	331	112	112	331	223
	8	231	312	123	123	312	231
	9	212	323	131	131	323	212

Stimuli key
First digit: airplane stimulus order; 1, 2, 3
Second digit: traffic-noise level; L_{eq} = 33, 43, 53 dB
Third digit: traffic-noise type; σ = 1.4, 3.6, 4.6 dB

TABLE CIII.- PRESENTATION ORDER FOR SECOND EXPERIMENT

Subject group	Presentation order								
	1	2	3	4	5	6	7	8	9
1	111	232	342	241	331	122	321	112	232
2	142	211	337	232	321	141	312	122	211
3	131	242	321	211	212	132	322	141	242
4	121	231	312	242	222	111	341	132	231
5	112	221	322	231	241	142	332	111	221
6	122	212	341	221	232	131	311	142	212
7	141	222	332	213	211	121	342	131	222
8	132	241	311	223	243	112	331	121	241

Stimuli key
First digit: airplane stimulus order; 1, 2, 3
Second digit: traffic-noise level; L_{eq} = 34, 41, 48, 55 dB
Third digit: traffic-noise type; σ = 1.4, 4.2 dB

APPENDIX D

INSTRUCTIONS AND SCORING SHEET FOR THE FIRST AND SECOND EXPERIMENTS

General Instructions for First Experiment

Thank you for volunteering to participate in a research program being carried out at the NASA Langley Research Center. We are studying peoples reactions to aircraft noises in order to contribute towards the development of a cumulative noise index for the prediction of general noise annoyance.

During the study you will hear various aircraft and other noises. None of these noises will be greater than those experienced on a daily basis by many community residents. As such, we anticipate that you will experience no undue physiological or psychological discomfort as a result to the noises. However, if at any time you feel indisposed to the extent that you cannot continue your role in the study, you will be free to leave.

There will be two occasions in all, arranged one week apart for your convenience, and each will last about two hours. Inasmuch as the data collected is dependent on your consistent participation for the entirety of the tests we hope you will be able to be present on each occasion.

If you would kindly sign the attached voluntary consent form, it will signify that you understand the purpose of the research and the technique to be used.

Specific Instructions for First Experiment

We would like you to help us investigate peoples reactions to individual aircraft noises.

Today there will be three sessions, each lasting about 30 minutes. During each session you will hear numerous aircraft noises. Your job will be to rate or score each aircraft on a response sheet in the following manner:

After listening to each aircraft noise, your rating should be recorded by circling the appropriate number on the scales provided on the response sheet. Each scale is numbered "0" through "9". You should choose a number which best reflects how annoying that particular aircraft noise was. For example, if you thought the noise was very annoying you would choose a higher number, closer to the "extremely annoying" end of the scale; if on the other hand you thought the aircraft noise was not annoying or only slightly annoying you would choose a lower number, closer to the "not annoying at all" end of the scale.

Please listen carefully and make your rating at the end of each aircraft noise. There are no correct answers, we just want a measure of your own personal reaction to each aircraft noise. For this reason, we request that you do not talk during the tests nor express any emotion which might influence the response of the other people in the room.

Thank you for helping us with this investigation.

General Instructions for Second Experiment

Thank you for volunteering to participate in a research program being carried out at the NASA Langley Research Center. We are studying peoples reactions to aircraft noises in order to contribute towards the development of a cumulative noise index for the prediction of general noise annoyance.

During the study you will hear various aircraft and other noises. None of these noises will be greater than those experienced on a daily basis by many community residents. As such, we anticipate that you will experience no undue physiological or psychological discomfort as a result of the noises. However, if at any time you feel indisposed to the extent that you cannot continue your role in the study, you will be free to leave.

If you would kindly sign the attached voluntary consent form, it will signify that you understand the purpose of the research and the technique to be used.

Specific Instructions for Second Experiment

We would like you to help us investigate peoples reactions to individual aircraft noises.

Today there will be nine sessions, each lasting about 10 minutes. During each session you will hear numerous aircraft noises. Your job will be to rate or score each aircraft on a response sheet in the following manner:

After listening to each aircraft noise, your rating should be recorded by circling the appropriate number on the scales provided on the response sheet. Each scale is numbered "0" through "9". You should choose a number which best reflects how annoying that particular aircraft noise was. For example, if you thought the noise was very annoying you would choose a higher number, closer to the "extremely annoying" end of the scale; if on the other hand you thought the aircraft noise was not annoying or only slightly annoying you would choose a lower number, closer to the "not annoying at all" end of the scale.

Please listen carefully and make your rating at the end of each aircraft noise. There are no correct answers, we just want a measure of your own personal reaction to each aircraft noise. For this reason, we request that you do not talk during the tests nor express any emotion which might influence the response of the other people in the room.

Thank you for helping us with this investigation.

APPENDIX D

Scoring Sheet

Subject Number ______________________ Name ______________________
Date ______________________

Aircraft Rating

Noise

1. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
2. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
3. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
4. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
5. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
6. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
7. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
8. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
9. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
10. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
11. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
12. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
13. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
14. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
15. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying
16. Not Annoying At All 0 1 2 3 4 5 6 7 8 9 Extremely Annoying

Group _____ Tape _________

Seat ______ Session ______

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TABLE I.- A-WEIGHTED PEAK AIRPLANE-NOISE LEVELS

[All values are given in decibels]

Type of airplane			
747	707	DC-10	727
First experiment			
62.1	65.3	55.3	65.6
69.3	71.6	60.6	70.2
76.3	77.3	67.1	77.0
83.3	83.9	74.5	84.4
Second experiment			
59.0	62.5	52.0	63.5
67.5	70.0	59.0	69.0
76.5	76.0	66.5	75.5
83.3	82.0	74.5	83.0

TABLE II.- ANALYSIS OF VARIANCE FOR THE FIRST EXPERIMENT

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio (a)
Between subjects	26	4990		
Between blocks	2	527	263.50	1.42[ns]
Subjects within blocks . . .	24	4463	185.96	
Within subjects	2565	16570		
Repeats	1	44.08	44.08	22.22[++]
A - airplane-noise stimuli . .	15	11220	748.10	377.07[++]
B - traffic-noise level . . .	2	180.2	90.10	45.41[++]
C - traffic-noise type	2	80.60	40.30	20.31[++]
A × B	30	42.65	1.42	
A × C	30	54.84	1.83	
B × C (linear term)	2	21.63	10.82	5.45[++]
Residual	2483	4926	1.98	
Total	2591	21560		

[a]Superscript ns indicates not significant, and ++ indicates significant at 1 percent.

TABLE III.- ANALYSIS OF VARIANCE FOR THE SECOND EXPERIMENT

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio (a)
S - Between subjects	23	3516.4294	152.888	
A - Airplane levels	15	15594.7965	1039.653	283.748^{++}
Error (S × A)	345	1264.1488	3.664	
B - Traffic levels	3	247.8942	82.631	15.869^{++}
Error (S × B)	69	359.2699	5.207	
C - Traffic types	1	1.2920	1.292	
Error (S × C)	23	146.4814	6.369	
A × B	45	148.9131	3.309	2.330^{++}
Error (S × A × B)	1035	1469.5479	1.420	
A × C	15	35.1924	2.346	1.431^{ns}
Error (S × A × C)	345	565.4092	1.639	
B × C	3	20.0244	6.675	1.083^{ns}
Error (S × B × C)	69	425.1709	6.162	
A × B × C	45	69.5120	1.545	1.042^{ns}
Error (S × A × B × C) . .	1035	1534.4176	1.483	
Total	3071	25398.4997		

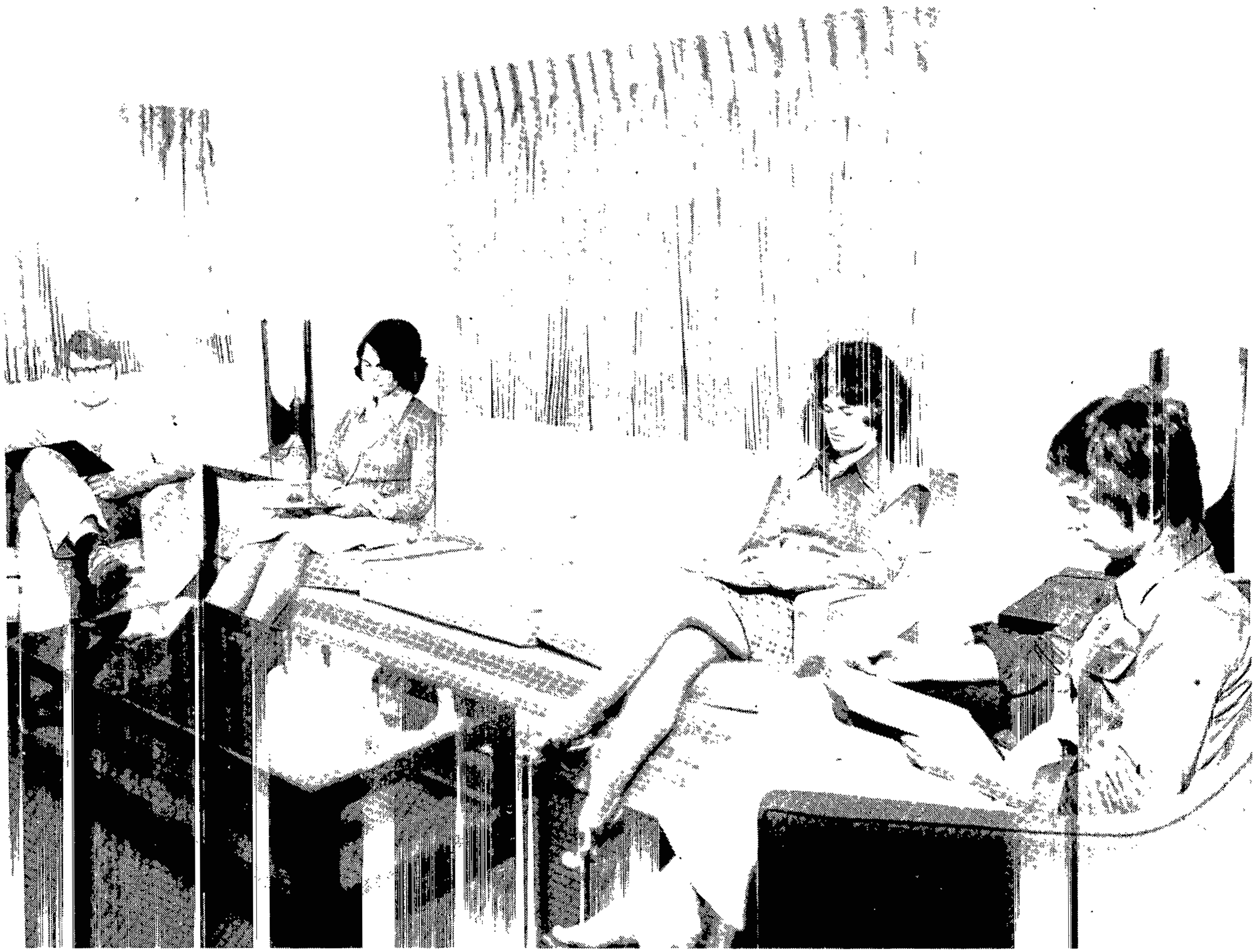
[a]Superscript ++ indicates significant at 1 percent, and ns indicates not significant.

TABLE IV.- LINEAR-REGRESSION ANALYSES OF MEAN ANNOYANCE RESPONSE ON AIRPLANE-NOISE LEVEL FOR DIFFERENT TRAFFIC LEVELS

Traffic-noise level, L_{eq}, dB	Mean	Intercept	Slope	Correlation coefficient
All levels combined . .	4.75	-12.44	0.246	0.986
34	5.133	-11.87	0.243	0.987
41	4.835	-13.21	.258	.988
48	4.60	-13.65	.261	.981
55	4.40	-11.38	.226	.976

TABLE V.- MEAN ANNOYANCE RESPONSES FOR AIRPLANE-NOISE STIMULI AT DIFFERENT TRAFFIC-NOISE LEVELS

Airplane-noise stimuli		Traffic-background-noise level for L_{eq}, dB, of -			
Type	L_{eq}, dB	34	41	48	55
DC-10	52.0	1.06	0.79	0.75	1.08
747	59.0	1.96	1.98	1.44	1.50
DC-10	59.0	2.33	1.85	1.48	2.21
707	62.5	3.29	2.56	2.40	2.65
727	63.5	3.77	2.86	2.79	2.44
747	67.5	4.17	4.10	3.38	3.10
DC-10	66.5	4.69	3.90	3.50	3.86
727	67.5	5.17	4.19	4.00	3.86
707	70.1	5.29	4.81	5.02	4.48
747	76.5	6.15	5.88	5.71	5.14
727	75.5	6.42	6.38	5.90	5.50
DC-10	74.0	6.71	6.50	6.35	5.71
707	76.0	7.19	6.98	6.94	6.33
747	83.5	8.02	8.06	7.75	7.25
727	83.0	8.12	8.21	8.04	7.71
707	82.0	8.27	8.29	8.21	7.50



L-76-3945

Figure 1.- Photograph of test facility.

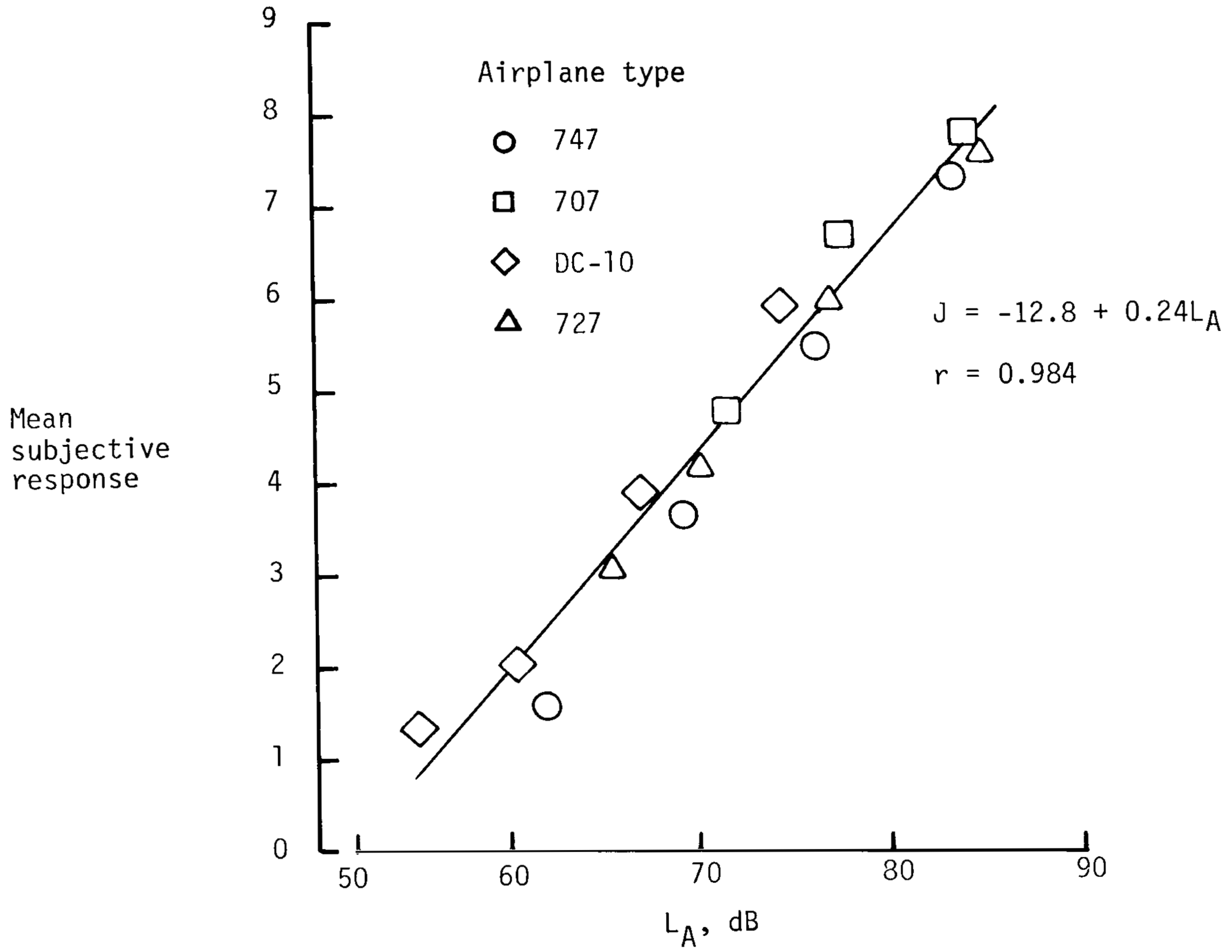
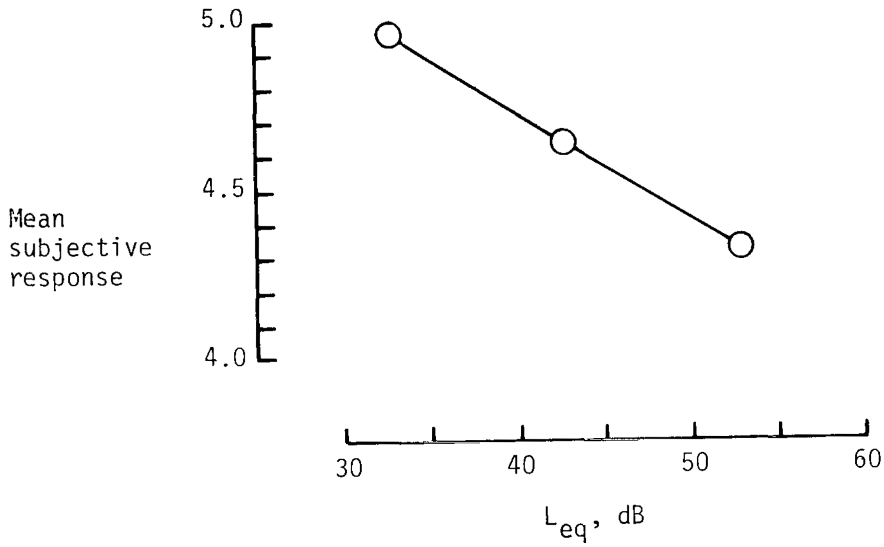
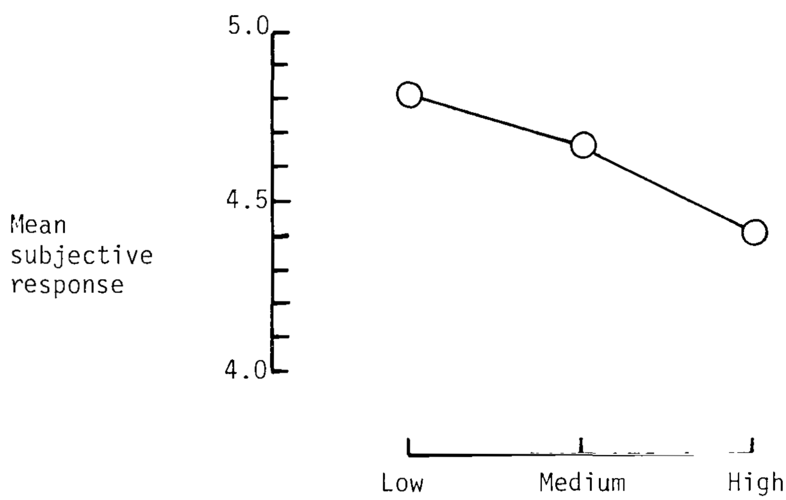


Figure 2.- Relationship of mean subjective response and airplane-noise level. First experiment.



(a) Traffic-noise level L_{eq}.



(b) Standard deviation of traffic-noise level.

Figure 3.- Relationship of mean subjective response and traffic-noise parameters. First experiment.

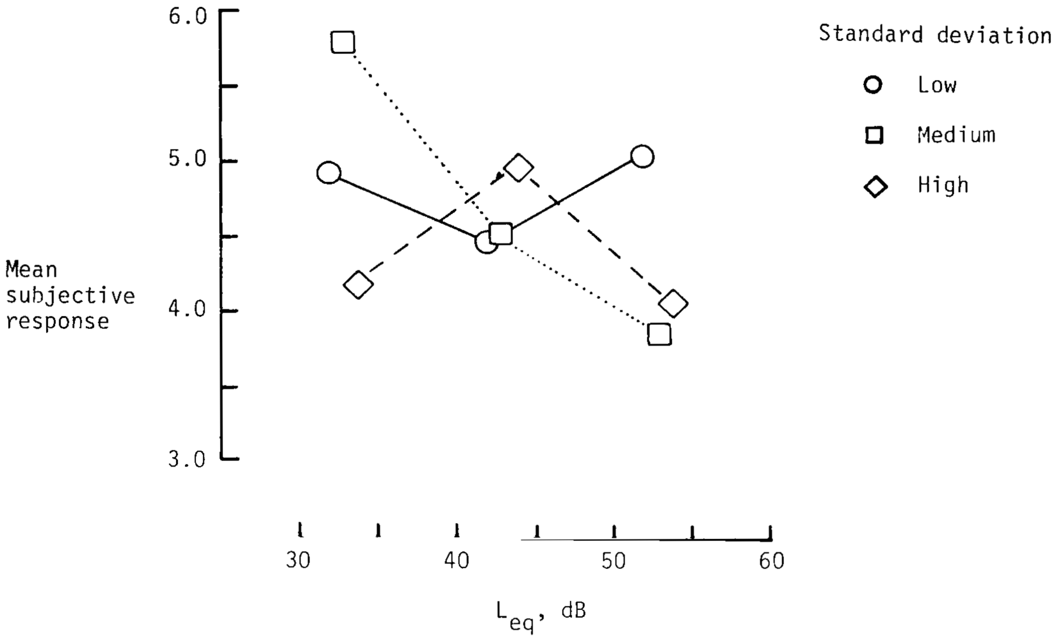


Figure 4.- Relationship of mean subjective response and traffic-noise level with traffic-noise type as a parameter. First experiment.

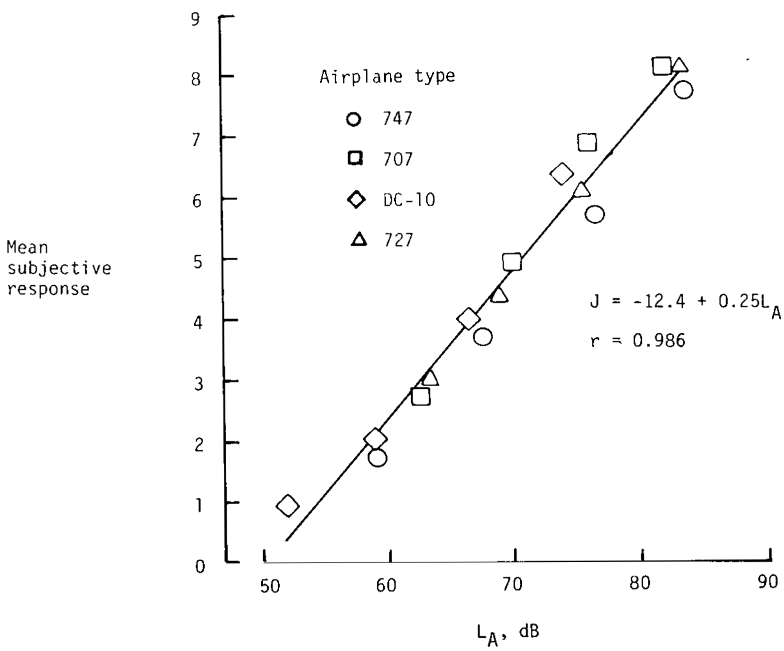


Figure 5.- Relationship of mean subjective response and airplane-noise level. Second experiment.

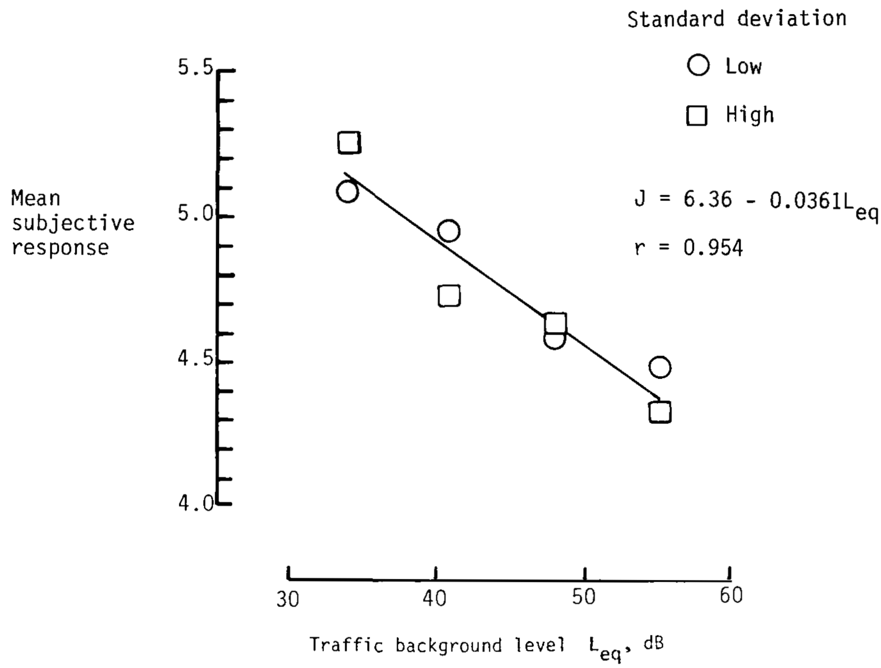


Figure 6.- Relationship of mean subjective response and traffic-noise level. Second experiment.

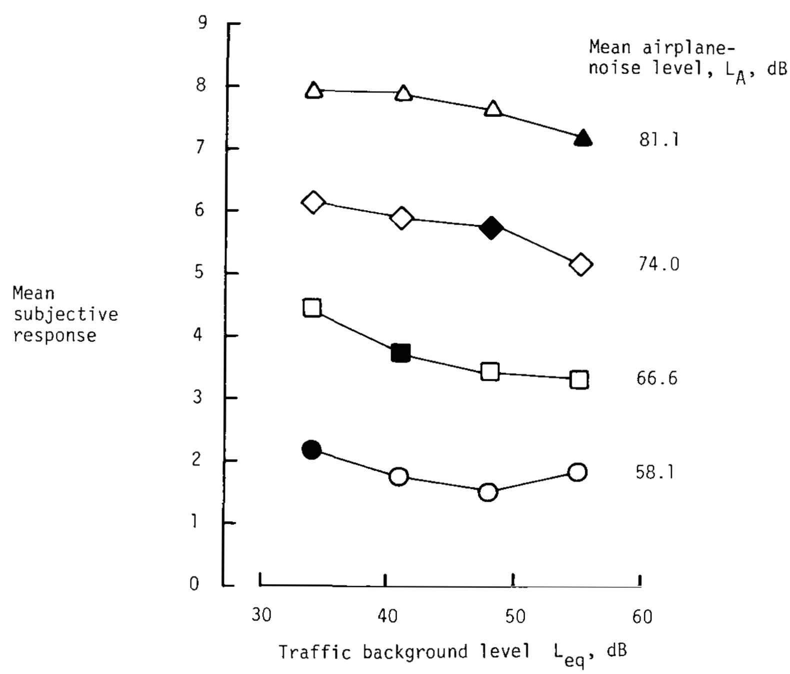


Figure 7.- Relationship of mean subjective response and traffic-noise level with peak airplane-noise level as a parameter. Second experiment. Solid symbols denote points of approximately constant ratio of airplane noise to traffic noise.