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ANNOYANCE CAUSED BY PROPELLER AIRPLANE FLYOVER NOISE: PRELIMINARY RESULTS

DAVID A. MCCURDY AND CLEMANS A. POWELL

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NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

Two laboratory experiments were conducted to examine the annoyance response of people to the noise of propeller airplane flyovers. The experiments were designed to provide information on the quantification of annoyance caused by propeller airplane noise. The specific items of interest were: (1) the annoyance prediction ability of current noise metrics; (2) the effect of tone corrections on prediction ability; (3) the effect of duration corrections on prediction ability; and (4) the effect of "critical band" corrections on the prediction ability of perceived noise level. This report presents preliminary analyses of the data obtained from the two experiments.

The first experiment examined propeller airplanes with maximum takeoff weights greater than or equal to 5700 kg. The second experiment examined propeller airplanes weighing 5700 kg or less. Included in the first experiment were recordings of 11 different propeller airplanes ranging in weight from 5700 to 70,300 kg. Operations included both takeoffs and landings. The second experiment included recordings of 14 different propeller airplanes weighing from 800 to 5700 kg. Operations included takeoffs, takeoffs with power cutbacks at 152 m altitude, landings, and constant altitude flyovers at 305 m. Also included in each experiment were recordings of takeoff and landing operations of five different commercial service jet airplanes. Each recording was presented at D-weighted sound pressure levels of 70, 80, and 90 dB to subjects in a testing room which simulates the outdoor acoustic environment. In each experiment the annoyance of each recording at each of the three levels was judged by 64 test subjects using a unipolar, 11 point scale from 0 to 10. Subjects judged 108 stimuli in the first experiment and 132 stimuli in the second experiment.

Perceived noise level predicted annoyance better than A, D, or E-weighted sound pressure level. Corrections for tones greater than or equal to 500 Hz generally improved prediction ability for the heavier propeller airplanes. Tone corrections generally degraded prediction ability for the light propeller airplanes. Duration corrections improved prediction ability for the heavier propeller airplanes and degraded prediction ability for the light propeller airplanes. The effect on prediction ability of critical band corrections to perceived noise level varied.

INTRODUCTION

Much attention has been directed towards understanding and quantifying the annoyance caused by aircraft flyover noise. Research in this area has concentrated primarily on the noise of jet airplanes and more recently on the noise of helicopters. Relatively little research has been conducted on annoyance caused by propeller airplanes. Because of the increased interest in propeller airplanes for general aviation, commuter, and energy-efficient long-haul operations, the need to understand and quantify annoyance caused by propeller airplanes has also increased. The research reported herein addresses that need.

One of the primary concerns in quantifying the annoyance caused by the noise of propeller airplanes arises because of the somewhat unusual spectral characteristics of the noise. Propeller noise, which can dominate the noise produced by such airplanes, typically consists of a number of harmonically related pure tone components. The fundamental frequency of these tones, which occurs at the propeller blade passage frequency, range from about 50 Hz to about 300 Hz for some proposed high speed turboprop airplanes. The number of higher harmonics and their strength relative to the fundamental depends primarily on propeller tip shape and helical Mach number. The annoyance caused by noise sources with strong tonal components has historically been more difficult to quantify than broadband noise. In the case of propeller noise, the uncertainty in accounting for tonal content is increased because less basic psychoacoustic research has been conducted in the lower frequency range than in the higher frequency range of tones from jet aircraft.

Another uncertainty in quantification of the low frequency content of propeller airplane noise is whether or not consideration should be given to the "critical band" concept (ref. 1). Annoyance metrics such as perceived noise level, PNL, are formulated around the summation of annoyance components based on one-third octave bands of noise. Below 500 Hz the bandwidth of the "critical bands" are thought to be considerably wider than one-third octave bands. Although this realization has been considered by a number of researchers (refs. 1 and 2 for example) little research has been conducted with noise sources with frequency characteristics such that differences in metrics using "critical band" or one-third octave band methods would be expected to be significant.

The purpose of the research conducted in the two experiments presented in this report was to provide information on the quantification of annoyance caused by propeller airplane noise. The specific objectives were: (1) to determine the ability of current noise metrics to assess or quantify annoyance caused by propeller airplane noise; (2) to detemine whether tone corrections improve or degrade the annoyance prediction ability of the metrics; (3) to determine whether duration corrections improve or degrade the annoyance prediction ability of the metrics; and (4) to determine if correction of PNL to account for "critical band" auditory theory offers any improvement in annoyance prediction ability.

To accomplish these objectives two laboratory annoyance judgment experiments were conducted. In the first experiment the annoyance to recorded sounds of propeller airplanes with maximum takeoff weights greater than or equal to 5700 kg were judged along with sounds of a number of commercial service jet airplanes.

In the second experiment the annoyance to recorded sounds of propeller airplanes with maximum takeoff weights less than or equal to 5700 kg were judged along with the sounds of the same jet airplanes. This report presents preliminary analyses of the data obtained from these two experiments which are directly applicable to the previously stated objectives.

NOISE MEASURES AND ABBREVIATIONS

Noise Measures

EPNL	effective perceived noise level, dB
L_A	A-weighted sound pressure level, dB
L_D	D-weighted sound pressure level, dB
L_E	E-weighted sound pressure level, dB
PNL	perceived noise level, dB

A more detailed description of the noise measures used in this report can be found in reference 3. EPNL is also defined in reference 4. PNL with one of the subscripts, K, M, or W represents the addition of critical band corrections to perceived noise level. The three different critical band corrections are defined in the Acoustical Data Analyses subsection of the Results and Discussion section of this report.

Abbreviations

ANSI	American National Standards Institute
FAR	Federal Aviation Regulation
L_S	subjective noise level, dB
T_1	tone correction method according to reference 4
T_2	tone correction method according to reference 4 modified so that no corrections are applied for tones identified in one-third-octave bands with center frequencies less than 500 Hz.

EXPERIMENTAL METHOD

Test Facility

The exterior effects room of the Langley aircraft noise reduction laboratory (see fig. 1) was used as the test facility in both experiments. This room has a volume of approximately 340 m^3 and a reverberation time of approximately 0.25 sec at 1000 Hz. The subjects pictured in figure 1 occupy the seats used during testing by each group of four subjects. The monophonic recordings of the aircraft-noise stimuli were played on a studio-quality tape recorder and presented to the subjects by means of four overhead loudspeakers. A commercially available noise reduction system which provided a nominal 30-dB increase in signal-to-noise ratio was used to reduce tape hiss to inaudible levels.

Test Subjects

One hundred twenty-eight subjects, 64 for each experiment, were randomly selected from a pool of local residents with a wide range of socioeconomic backgrounds and were paid to participate in the experiments. All test subjects were given audiograms prior to the experiment to verify normal hearing. (ANSI 1969). Table I gives the sex and age data for the subjects in each experiment.

Noise Stimuli

The noise stimuli for both experiments consisted of loudspeaker-reproduced recordings of actual flight operations. The recordings of commercial service jet airplanes were made on the centerline approximately 5000 m from the brake release point. The propeller airplane recordings were made at several different airports and the distances from brake release and touchdown varied. The propeller airplane recordings were made on or near the centerline at each location. Due to the higher flight profiles and lower source noise levels of the propeller airplanes, the recording sites for propeller airplanes were located closer to the brake release or touchdown points than those for the commercial service jet airplanes. Microphones were located over dirt or grass approximately 1.2 m above ground level.

First Experiment Stimuli.- The first experiment examined propeller airplanes with maximum takeoff weights greater than or equal to 5700 kg. One hundred and eight stimuli were presented to the subjects. Of these 108 stimuli, 96 served as the basic data set, 7 were included for converting subjective responses to subjective decibel levels, 3 were included as a common reference with another study, and 2 were repeats of stimuli added to even out the number of stimuli per session. The 96 basic stimuli consisted of takeoff and landing operations of 11 propeller and 5 jet airplanes presented at nominal L_D values of 70, 80, and 90 dB. The types of airplanes and some specifications of each are given in Table II.

Second Experiment Stimuli.- The second experiment examined propeller airplanes with maximum takeoff weights less than or equal to 5700 kg. One hundred and thirty-two stimuli were presented to the subjects. Of the 132 stimuli, 108 served as the basic data set, 7 were included for converting subjective responses to subjective decibel levels, 3 were included as a common reference with another study, 12 were a pilot study of microphone height effects, and 2 were repeats of stimuli added to even out the number of stimuli per session. Fourteen propeller and 5 jet airplanes were included in the 108 basic stimuli. Operations included takeoff, landing, takeoff with power cutback of 152 m altitude, and constant altitude flyover at 305 m. However, not every airplane was represented by every operation. Each combination of airplane and operation that was included was presented at L_D values of 70, 80, and 90 dB. A summary of the types of airplanes, some specifications of each, and the type of operations included is given in

Table III. The commercial service jet stimuli were identical for both experiments. Also the Swearingen Metro II takeoff and landing was included in the basic data set in both experiments.

Experiment Design

Numerical category scaling was chosen as the psychophysical method for both experiments. The choice was made to maximize the number of stimuli that could be judged in the fixed amount of time available. The scale selected was a unipolar, 11 point scale from 0 to 10. The end points of the scale were labeled "EXTREMELY ANNOYING" and "NOT ANNOYING AT ALL." The term "ANNOYING" was defined in the subject instructions as "UNWANTED, OBJECTIONBLE, DISTURBING, OR UNPLEASANT."

For each experiment, the stimuli were divided into two sets of four groups or tapes. The first set of four tapes contained all the stimuli in the experiment. The second set contained the same stimuli as the first but in reverse order. There were 27 stimuli per tape in the first experiment and 33 per tape in the second experiment. The stimuli were divided between tapes so that aircraft, levels, and operations were equally represented on each tape. The order of the stimuli on the tape was then randomly selected. A period of approximately 10 sec was provided after each stimulus for the subjects to make and record their judgments. Each tape served as a test session for the subjects and required approximately 20 min for playback in the first experiment and 30 min in the second experiment.

The 64 test subjects in each experiment were divided into 16 groups of 4 subjects. The first four tapes were presented to the first eight groups of subjects and the second four tapes were presented to the second eight groups of subjects. To prevent subject fatigue and other temporal effects from unduly influencing the results, the order in which the tapes were presented was varied to provide a balanced presentation.

Procedure

Upon arrival at the laboratory, the subjects were seated in a conference room and each was given a set of instructions and a consent form. Copies of these items for the first experiment are given in the appendix. In the second experiment, these items were identical except that the length of the session was changed from 20 min to 30 min and the number of aircraft sounds was changed from 27 to 33. After reading the instructions and completing the consent form, the subjects were given a brief verbal explanation of the cards used for recording judgments and were asked if they had any questions. The subjects were then taken into the test facility and randomly assigned to the four seat locations. Three practice stimuli were presented to the subjects while the test conductor remained in the test facility. In order for the subjects to gain experience in scoring the sounds, they were instructed to make and record judgments of the practice stimuli. After asking again for any questions about the test, the test conductor issued scoring cards for the first session and left the facility. Then, the first of four test sessions began. After the conclusion of each session, the test conductor reentered the test facility, collected the scoring cards, and issued new scoring cards for the next session. Between the second and third sessions, the subjects were given a 15 min rest period outside the test facility.

RESULTS AND DISCUSSION

Acoustic Data Analyses

Each stimulus was analyzed to provide one-third-octave-band sound pressure levels from 20 Hz to 20 kHz for use in computing a selected group of commonly used noise metrics or rating scales. The measurements were made with a 1.27 cm diameter condenser microphone and a real time, one-third-octave analysis system which used digital filtering. The microphone was located at the head position of the subject pictured in figure 1 in the first row to the reader's right. No subjects were present during the measurements. To account for spectral differences in the noise stimuli for this preliminary analysis, the noise metrics considered were limited to the three weighted procedures L_A, L_D, and L_E and the calculation procedure PNL. In addition, three types of critical band corrections were applied to PNL, resulting in a total of seven procedures or noise metrics.

The first critical band correction procedure was suggested in reference 5. In this procedure, the increased bandwidths of critical bands below 400 Hz are approximated by groups of one-third octave bands. The groups are the bands with center frequencies: 250 and 315 Hz; 125, 160, and 200 Hz; and 50, 63, 80 and 100 Hz. Within each group the band levels are summed on an energy basis. The summed band levels are assigned to the band center frequency having the greatest intensity within the group. The PNL calculation procedure then uses these "critical bands" instead of the one-third octave bands below 400 Hz. The metric using this procedure will be designated as PNL_K in further discussions in this report.

The second critical band correction procedure used the same groups for summing the one-third octave bands. The summed band levels, however, were assigned to the band center frequency responsible for the greatest "Noy" value within the group before summing. The metric using this procedure will be designated as PNL_M.

The third critical band correction procedure also used the same groups of one-third octave bands. In this case, the "NOY" values of the one-third octave band levels were added on an energy basis within each group. The resultant "NOY" values for all critical bands were then summed using the PNL procedure. The metric using this procedure will be designated as PNL_W.

Six different variations of each of the seven previously described noise metrics were calculated. The first was the peak or maximum level occurring during a flyover noise. Two more variations were calculated by applying two different tone corrections. Three more variations were achieved by applying duration corrections to the non-tone corrected level and the two tone-corrected levels. The duration correction and the first tone correction, T_1, are identical to those used in the effective perceived noise level procedure defined in the Federal Aviation Administration FAR 36 regulation (ref. 4). The second tone correction, T_2, is identical to the first except that no corrections are applied for tones identified in bands with center frequencies less than 500 Hz.

Subjective Data Analyses

The means (across subjects) of the judgments were calculated for each stimulus. These mean annoyance scores were converted to "subjective noise levels", L_S, having decibel-like properties through the following process. Included in each experiment for the purpose of converting the mean annoyance scores to L_S values were seven presentations of the Boeing 727 takeoff recording ranging in values of L_D from 65 to 95 dB in 5 dB increments. Three additional presentations of the recording, at 70, 80, and 90 dB, were included in each experiment's basic data set. For each experiment separately, third order polynomial regression analyses were performed using data obtained for these 10 stimuli. The dependent variable was the calculated PNL and the independent variable was the mean annoyance score for each of the 10 stimuli. Figure 2 presents the two sets of data and the resulting best fit curves. The regression equations thusly determined were subsequently used to predict the level of the Boeing 727 takeoff noise which would produce the same mean annoyance score as each of the other noise stimuli in the separate experiments. These levels were then considered as the "subjective noise level" for each stimulus.

Comparison of Results for Propeller and Jet Airplanes

In both experiments some differences in results were found between propeller airplanes and jet airplanes. This section presents results for the two most common metrics used for aircraft noise assessment, peak L_A and EPNL.

First Experiment.- Figure 3 presents the relationships between the subjective noise level and the measured noise levels, peak L_A and EPNL, for the heavier propeller airplanes and the jet airplanes. Results for linear least squares regression analyses of these data are presented in Table IV. No significant differences in slopes between the two airplane types were found for either metric. For a given peak L_A, jet airplanes were judged, on the average, approximately 2.5 dB more annoying than the propeller airplanes. For a given EPNL, on the average, no differences in judged annoyance were found between the jet and propeller airplane noises. The regression analyses indicated more scatter in the data for propeller airplanes than for jets for peak L_A but less scatter for propeller airplanes for EPNL. More details as to the differences between metrics will be given in later sections.

Second Experiment.- Comparisons of the results obtained for the light propeller airplanes and the jet airplanes of this experiment are presented in figure 4. A summary of the regression analyses for these data are presented in Table V. No significant differences were found between the slopes for the two airplane types for either metric. There were differences, however, on the average between the two airplane types for both metrics. The light propeller airplanes were found to be about 6 dB less annoying than the jet airplanes for peak L_A and about 4 dB less annoying for EPNL. The regression results of this experiment also indicated more scatter in the data for propeller airplanes than for jets using peak L_A but indicated only slightly less scatter for propeller airplanes using EPNL.

Between Experiments.- The results of the two experiments for the jet airplanes were remarkably consistent. No significant differences were found in the regression analyses (Tables IV and V) between the two experiments for either peak L_A or EPNL. Although the original recorded airplane noises were identical, the noises presented to the completely different sets of subjects of the two experiments were from different copies of the originals. The implications of these findings are that the two sets of subjects were providing very consistent judgments of the noise relative to the Boeing 727 takeoff noise used as a reference for converting judgments to subjective noise levels.

The results of the two experiments for the propeller airplanes were not as consistent. The slopes for the two experiments were slightly different; the light propeller airplane slopes were less than the heavier propeller airplane slopes for both peak L_A and EPNL. The annoyance to the light propeller airplanes was also on the average less than that to the heavier propeller airplanes for both peak L_A and EPNL.

Comparison of Noise Metrics for Propeller Airplanes

The major question of importance is which combination of calculation procedure, tone correction, duration correction, and critical band correction best predicts the annoyance caused by propeller airplane noise. In order to investigate this prediction ability in detail, the differences between the subjective noise level, L_S and the calculated noise level for each variation of the noise metrics investigated were determined for each stimulus in each experiment. These differences were considered to be the "prediction error" for each stimulus and noise metric variation. The standard deviation of the prediction errors for each noise metric variation is a measurement of how accurately the variation predicts annoyance. The smaller the standard deviation is, the greater the prediction accuracy.

Tables VI and VII give the standard deviations of prediction error for each noise metric and correction examined for the propeller airplane noises in the first and second experiments respectively. The standard deviations are averaged in three ways: (1) across the six variations of tone and duration corrections; (2) across the noise metrics; and (3) across the noise metrics and across the three tone corrections. The information in these tables will be used in the following discussion of each experiment.

First Experiment.- Comparison of the average standard deviations, across the tone and duration corrections, of L_A, L_D, L_E, and PNL in Table VI indicates that annoyance was predicted best by PNL, L_D, L_A, and L_E, in that order. PNL and L_E were consistently the best and the worst predictors for each combination of tone and duration corrections; whereas, the order of L_D and L_A varied depending on the tone correction. The addition of critical band corrections to PNL in general resulted in a further improvement in the average standard deviations of about 0.1 dB. The critical band correction which provided the greatest improvement depended on the particular combination of tone and duration corrections used.

Comparison of the average standard deviations, across noise metrics, of the no tone correction, the T_1 tone correction, and the T_2 tone correction variations in Table VI indicates that the T_2 tone correction generally improved prediction ability and the T_1 tone correction generally degraded prediction ability. When the noise metrics are considered individually, this trend holds true except for the cases of duration corrected L_A and critical band corrected PNL's without duration corrections.

Comparison of the average standard deviations, across noise metrics, of the variations with and without duration corrections in Table VI indicates that the addition of the duration correction improved prediction ability. The only case in which the duration correction degraded prediction ability is PNL_W with T_1 tone corrections.

PNL with duration corrections and T_2 tone corrections predicted annoyance better than any other variation of L_A, L_D, L_E, or PNL without critical band corrections. Addition of critical band corrections to this variation of PNL improved the prediction ability slightly. PNL_W with duration and T_2 tone corrections had the smallest standard deviation of prediction error.

It should be emphasized that the largest difference in the standard deviations of prediction error was less than 1.0 dB for any two specific combinations of noise metric, tone correction, and duration correction. Because of interrelationship between the data cases, statistical tests for significance of differences in the standard deviations of prediction error are not straight forward. As a consequence, no "best" predictor of annoyance can be reliably singled out. The general trends found in the data were for the most part consistent across the different cases examined. The PNL metric for frequency weighting, corrections for tones greater than or equal to 500 Hz, and correction for duration each offered improved annoyance prediction for the heavier propeller airplanes.

Second Experiment.- Comparison of the average standard deviations, across tone and duration, of L_A, L_D, L_E, and PNL in Table VII indicates that annoyance was predicted best by PNL, L_A, L_D, and L_E in that order. PNL was consistently the best predictor for each combination of tone and duration corrections; whereas, the order of L_A, L_D, and L_E depended on the combination. The addition of critical band corrections to PNL's not corrected for duration degraded prediction ability. The addition of critical band corrections to duration corrected PNL's improved prediction ability slightly; however, the best critical band correction and the amount of improvement varied depending on the tone correction used.

Comparison of the average standard deviations, across noise metrics, of the no tone correction, the T_1 tone correction, and the T_2 tone correction variations in Table VII indicates that both tone corrections degraded prediction ability, T_1 more so than T_2. This trend was consistent for each noise metric with and without duration corrections.

Comparison of the average standard deviations, across noise metrics, of the variations with and without duration corrections in Table VII indicates that the addition of the duration correction degraded prediction ability. This trend is true for every metric except L_A. Duration corrections improved the prediction ability of L_A, but by amounts less than 0.1 dB.

Peak PNL, that is PNL with no duration correction and no tone correction, predicted annoyance better than any other variation of any of the noise metrics, including PNL's with critical band corrections. The addition of critical band correctons to peak PNL degraded prediction ability slightly. The difference in standard deviations between peak PNL and peak L_D, the best non-PNL predictor, was 0.34 dB. The difference in standard deviations between peak PNL and peak L_A, a commonly used predictor, was 0.46 dB.

As in the first experiment, it should be emphasized that no "best" predictor of annoyance can be reliably singled out. The general trends found in the data were for the most part consistent across the different cases examined. The PNL metric for frequency weighting, no correction for tones, and no correction for duration resulted in the smallest standard deviation of prediction error for the light propeller airplanes.

Duration.- A word of caution is in order concerning the duration correction results for both experiments discussed in the preceding paragraphs. Research on annoyance to commercial service jet airplanes showed that different studies often yielded widely varying conclusions on the need for duration corrections. Two reasons for this variation were differences in experimental design and the inability to independently vary duration and other noise characteristics such as spectral content when using recordings of real aircraft (ref. 6).

Both of these problems may also affect the results of propeller noise studies. In addition, the propeller airplane recordings used in the study, particularly those for the light propeller airplanes, were made at locations relatively close to liftoff and touchdown points and may not adequately represent the range of durations to which the surrounding communities are exposed. A definitive answer to the question of the need for duration corrections in assessing propeller airplane noise will require an experiment designed specifically to study duration with carefully selected stimuli in which other noise characteristics are controlled over a wide range of durations.

CONCLUSIONS

Two laboratory experiments were conducted to provide information on the quantification of annoyance caused by propeller airplane noise. The first experiment examined 11 propeller airplanes with maximum takeoff weights greater than or equal to 5700 kg. The second experiment examined 14 propeller airplanes weighing 5700 kg or less. Also included in each experiment were 5 commercial service jet airplanes. In each experiment, 64 subjects made annoyance judgments of the stimuli in a testing room which simulates the outdoor acoustic environment. Based on the preliminary results presented in this paper, the following conclusions were noted:

1. For a given peak A-weighted sound pressure level jet airplanes were judged, on the average, 2.5 dB more annoying than the heavier propeller airplanes and 6 dB more annoying than the light propeller airplanes. For a given effective perceived noise level, jet airplanes were judged equally annoying to the heavier propeller airplanes and 4 dB more annoying than the light propeller airplanes.

2. In both experiments the frequency weighting procedure found to be most accurate in predicting annoyance caused by propeller airplane noise was perceived noise level.
3. For the heavier propeller airplanes, prediction ability was improved by the addition to perceived noise level of a tone correction similar to the one used in effective perceived noise level but limited to tones in one-third octave bands with center frequencies greater than or equal to 500 Hz. Application of the effective perceived noise level tone correction without modification degraded prediction ability.
4. For light propeller airplanes the addition of either tone correction to perceived noise level degraded prediction ability.
5. The addition of a duration correction to perceived noise level improved prediction ability for the heavier propeller airplanes but degraded prediction ability for the light propeller airplanes.
6. Overall, the addition of critical band corrections to perceived noise level improved annoyance prediction ability. However, the results varied depending on the combination of tone and duration corrections used and, therefore, further study is required before a definitive conclusion concerning their application can be reached.

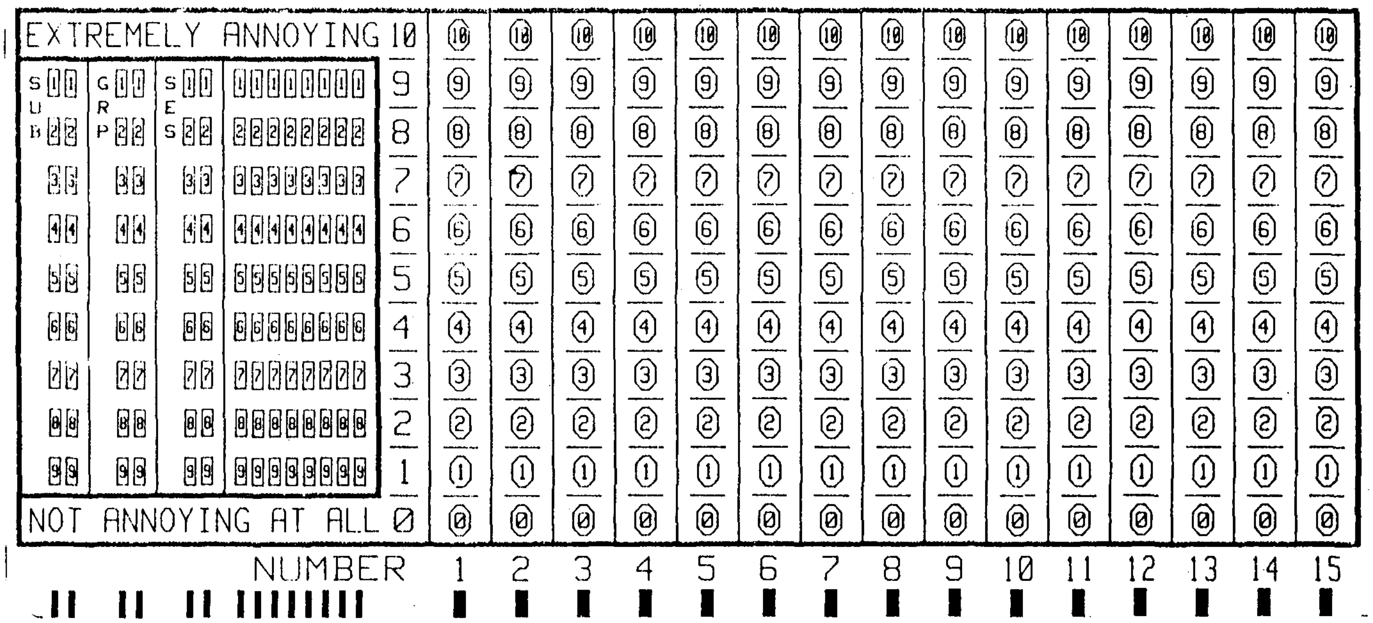
APPENDIX

Instructions and Consent Form

INSTRUCTIONS

The experiment in which you are participating will help us understand the characteristics of aircraft sounds which can cause annoyance in airport communities. We would like you to judge how ANNOYING some of these aircraft sounds are. By ANNOYING we mean - UNWANTED, OBJECTIONABLE, DISTURBING, OR UNPLEASANT.

The experiment consists of four 20 minute sessions. During each session 27 aircraft sounds will be presented for you to judge. You will record your judgments of the sounds on computer cards like the one below:



After each sound there will be a few seconds of silence. During this interval, please indicate how annoying you judge the sound to be by marking the appropriate numbered circle on the computer card. The number of each sound is indicated across the bottom of the card. If you judge a sound to be only slightly annoying, mark one of the numbered circles close to the NOT ANNOYING AT ALL end of the scale, that is a low numbered circle near the bottom of the card. Similarly, if you judge a sound to be very annoying, then mark one of the numbered circles close to the EXTREMELY ANNOYING end of the scale, that is a high numbered circle near the top of the card. A moderately annoying judgment should be marked in the middle portion of the scale. In any case, make your mark so that the circle that most closely indicates your annoyance to the sound is completely filled in. There are no right or wrong answers; we are only interested in your judgment of each sound.

Before the first session begins you will be given a practice computer card and three sounds will be presented to familiarize you with making and recording judgments. I will remain in the testing room with you during the practice time to answer any questions you may have.

Thank you for your help in conducting the experiment.

VOLUNTARY CONSENT FORM FOR SUBJECTS FOR HUMAN RESPONSE TO AIRCRAFT NOISE AND VIBRATION

I understand the purpose of the research and the technique to be used, including my participation in the research, as explained to me by the Principal Investigator (or qualified designee).

I do voluntarily consent to participate as a subject in the human response to aircraft noise experiment to be conducted at NASA Langley Research Center on ______________________________
Date

I understand that I may at any time withdraw from the experiment and that I am under no obligation to give reasons for withdrawal or to attend again for experimentation.

I undertake to obey the regulations of the laboratory and instructions of the Principal Investigator regarding safety, subject only to my right to withdraw declared above.

I affirm that, to my knowledge, my state of health has not changed since the time at which I completed and signed the medical report form required for my participation as a test subject.

____
Signature of Subject

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TABLE I.- TEST SUBJECTS

EXPERIMENT	SEX	NUMBER OF PARTICIPANTS	MEAN AGE	MEDIAN AGE	AGE RANGE
1	MALE	18	28	26.5	20-53
	FEMALE	46	36	36	21-67
	ALL SUBJECTS	64	34	33	20-67
2	MALE	16	32	27.5	20-65
	FEMALE	48	40	41.5	18-74
	ALL SUBJECTS	64	38	35.5	18-74

TABLE II.- AIRPLANES IN FIRST EXPERIMENT

AIRPLANE	NUMBER OF ENGINES	ENGINE TYPE	MAXIMUM TAKEOFF WEIGHT, kg	OPERATIONS*
Beechcraft Super King Air 200	2	turboprop	5,700	T,L
DeHavilland Canada DHC7 Dash-7	4	turboprop	20,000	T,L
Embraer EMB 110 Bandeirante	2	turboprop	5,700	T,L
Gulfstream American Gulfstream I	2	turboprop	15,900	T,L
Lockheed C-130	4	turboprop	70,300	T,L
Lockheed P-3	4	turboprop	61,200	T,L
Nihon YS-11	2	turboprop	24,500	T,L
Nord Aviation 262	2	turboprop	10,600	T,L
Shorts 330	2	turboprop	10,300	T,L
Swearingen Metro II	2	turboprop	5,700	T,L
Vickers Viscount	4	turboprop	32,900	T,L
Airbus Industrie A-300	2	turbofan	$\geq$142,000	T,L
Boeing 707	4	turbofan	$\geq$117,000	T,L
Boeing 727-200	3	turbofan	86,900	T,L
McDonnell Douglas DC-9	2	turbofan	$\geq$ 41,100	T,L
McDonnell Douglas DC-10	3	turbofan	$\geq$206,400	T,L

*T - takeoff, L - landing

TABLE III.- AIRPLANES IN SECOND EXPERIMENT

AIRPLANE	NUMBER OF ENGINES	ENGINE TYPE	MAXIMUM TAKEOFF WEIGHT, kg	OPERATIONS*
Beechcraft Bonanza V	1	piston	1,500	T
Cessna 172	1	piston	1,100	T
Cessna 177	1	piston	1,100	T
Cessna 210	1	piston	1,700	T,C,F
Cessna 335	2	piston	2,700	T,C
Cessna 425	2	turboprop	3,700	T,C
Gulfstream American Tiger	1	piston	1,100	T
Mitsubishi MU-2	2	turboprop	5,200	T,L
Mooney 231	1	piston	1,300	T,C
Piper Cheyenne II	2	turboprop	4,100	T,C
Piper Seneca III	2	piston	2,100	T,C,F
Piper Supercub	1	piston	800	T
Rockwell Turbo Commander 690B	2	turboprop	4,700	T
Swearingen Metro II	2	turboprop	5,700	T,L,C,F
Airbus Industrie A-300	2	turbofan	$\geq$142,000	T,L
Boeing 707	4	turbofan	$\geq$117,000	T,L
Boeing 727-200	3	turbofan	86,900	T,L
McDonnell Douglas DC-9	2	turbofan	$\geq$ 41,100	T,L
McDonnell Douglas DC-10	3	turbofan	$\geq$206,400	T,L

*T - takeoff, L - landing, C - takeoff with power cutback at 152m altitude, F - constant altitude flyover at 305 m

TABLE IV.- REGRESSION ANALYSES FOR PEAK L_A AND EPNL FOR THE FIRST EXPERIMENT

AIRPLANE TYPE	INTERCEPT	SLOPE	CORRELATION COEFFICIENT	STANDARD ERROR OF ESTIMATE, dB
Peak L_A				
Jet	10.17	1.047	0.967	2.33
Propeller	4.83	1.087	.942	3.24
EPNL				
Jet	1.50	1.007	.939	3.16
Propeller	-9.36	1.142	.958	2.79

TABLE V.- REGRESSION ANALYSES FOR PEAK L_A AND EPNL FOR THE SECOND EXPERIMENT

AIRPLANE TYPE	INTERCEPT	SLOPE	CORRELATION COEFFICIENT	STANDARD ERROR OF ESTIMATE, dB
Peak L_A				
Jet	8.33	1.074	0.966	2.34
Propeller	11.72	.944	.932	3.11
EPNL				
Jet	1.94	1.004	.940	3.11
Propeller	1.92	.952	.934	3.05

TABLE VI.- STANDARD DEVIATIONS OF PREDICTION ERROR FOR PROPELLER AIRPLANES IN THE FIRST EXPERIMENT

METRIC	NO DURATION CORRECTION			DURATION CORRECTED			AVERAGE ACROSS TONE AND DURATION
	NO TONE CORRECTION	T_1	T_2	NO TONE CORRECTION	T_1	T_2	
L_A	3.3008	3.3050	3.0906	3.1050	3.0838	2.8158	3.1168
L_D	3.1206	3.3456	3.0563	2.9653	3.1496	2.7779	3.0692
L_E	3.4107	3.5075	3.2553	3.1114	3.2166	2.8711	3.2288
PNL	2.8108	3.1122	2.7366	2.7574	2.9966	2.5945	2.8347
PNL_K	2.7692	2.9782	2.7789	2.6251	2.7900	2.5509	2.7487
PNL_M	2.7588	2.9846	2.7891	2.6257	2.8078	2.5550	2.7535
PNL_W	2.7162	2.9326	2.7678	2.5755	3.0048	2.5335	2.7551
Average Across Metric	2.9839	3.1665	2.9249	2.8236	3.0070	2.6712	
Average Across Metric and Tone	3.0251			2.8340			

TABLE VII.- STANDARD DEVIATIONS OF PREDICTION ERROR FOR PROPELLER AIRPLANES IN THE SECOND EXPERIMENT

METRIC	NO DURATION CORRECTION			DURATION CORRECTED			AVERAGE ACROSS TONE AND DURATION
	NO TONE CORRECTION	T_1	T_2	NO TONE CORRECTION	T_1	T_2	
L_A	3.1213	3.1967	3.1718	3.0243	3.1957	3.0926	3.1337
L_D	3.0052	3.2329	3.0844	3.1582	3.3931	3.2370	3.1851
L_E	3.0789	3.2353	3.1447	3.1482	3.3856	3.2331	3.2043
PNL	2.6659	2.8419	2.7034	2.7893	3.0589	2.8894	2.8248
PNL_K	2.6949	2.8590	2.7490	2.7932	2.9872	2.8368	2.8200
PNL_M	2.6896	2.8618	2.7469	2.7503	2.9918	2.8471	2.8146
PNL_W	2.6736	2.8645	2.7442	2.7759	2.9742	2.8294	2.8103
Average Across Metric	2.8476	3.0132	2.9063	2.9199	3.1409	2.9951	
Average Across Metric and Tone	2.9222			3.0186			

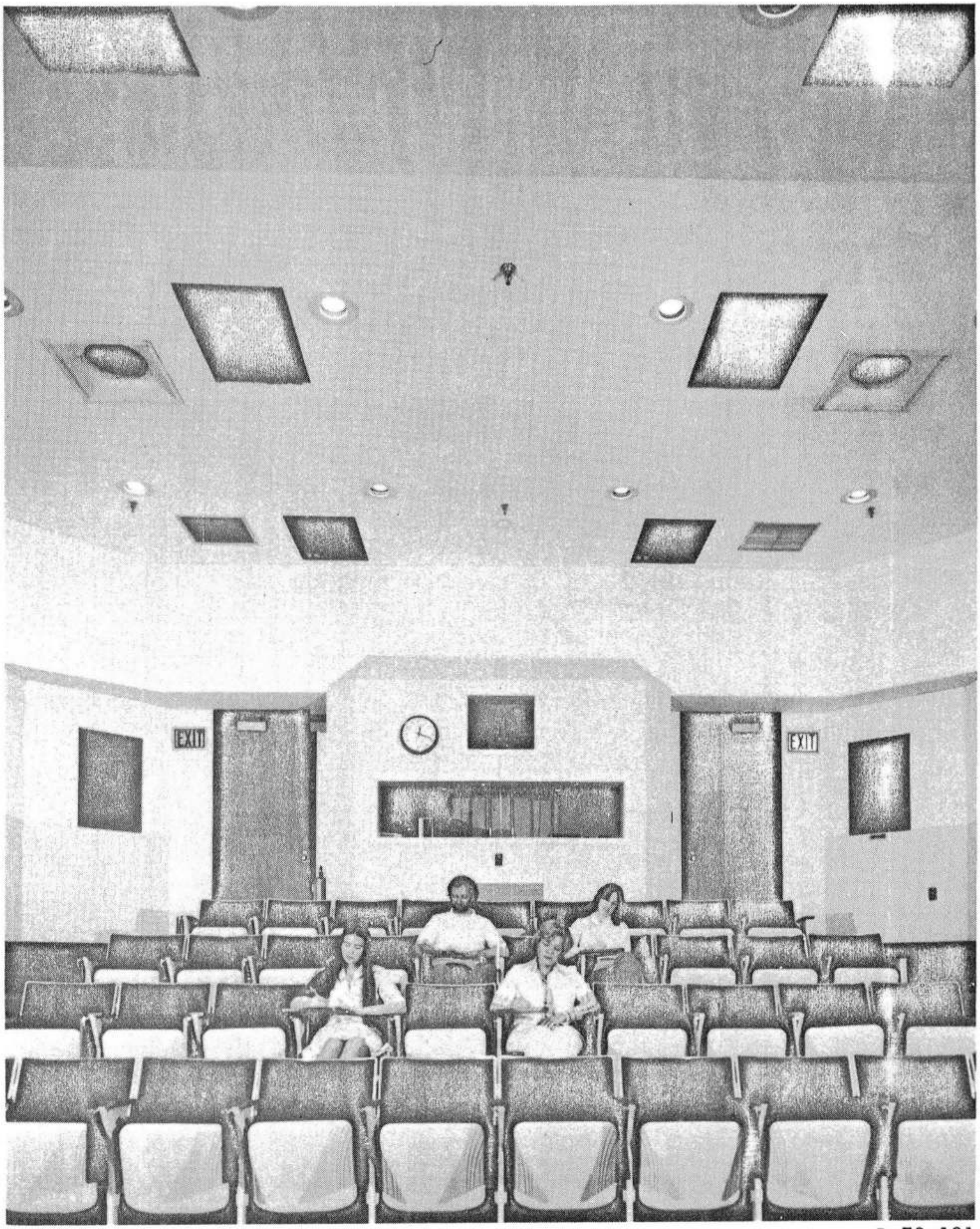

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Figure 1.- Subjects in exterior effects room of the Langley aircraft noise reduction laboratory.

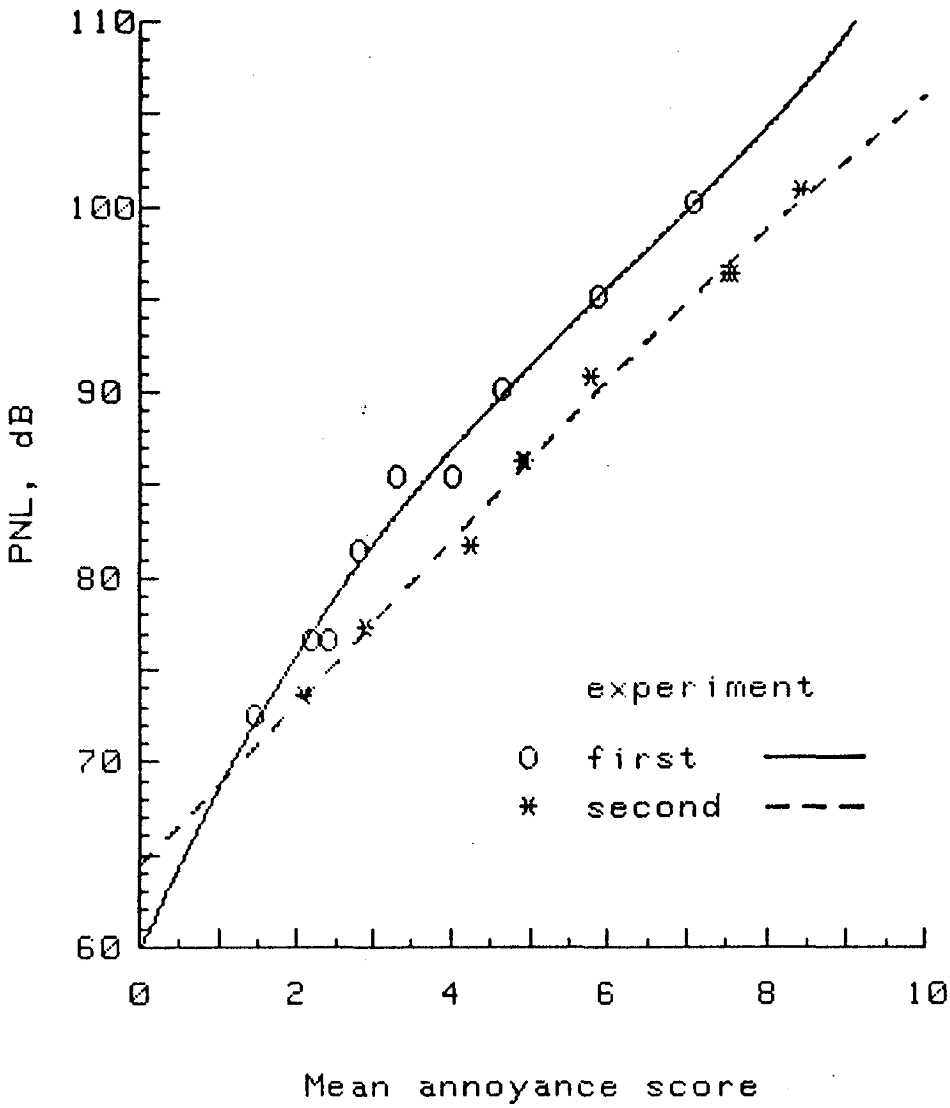

Figure 2.- Regression analyses of PNL on mean annoyance scores for the Boeing 727 takeoff stimuli used to convert annoyance judgments to subjective noise levels, L_S.

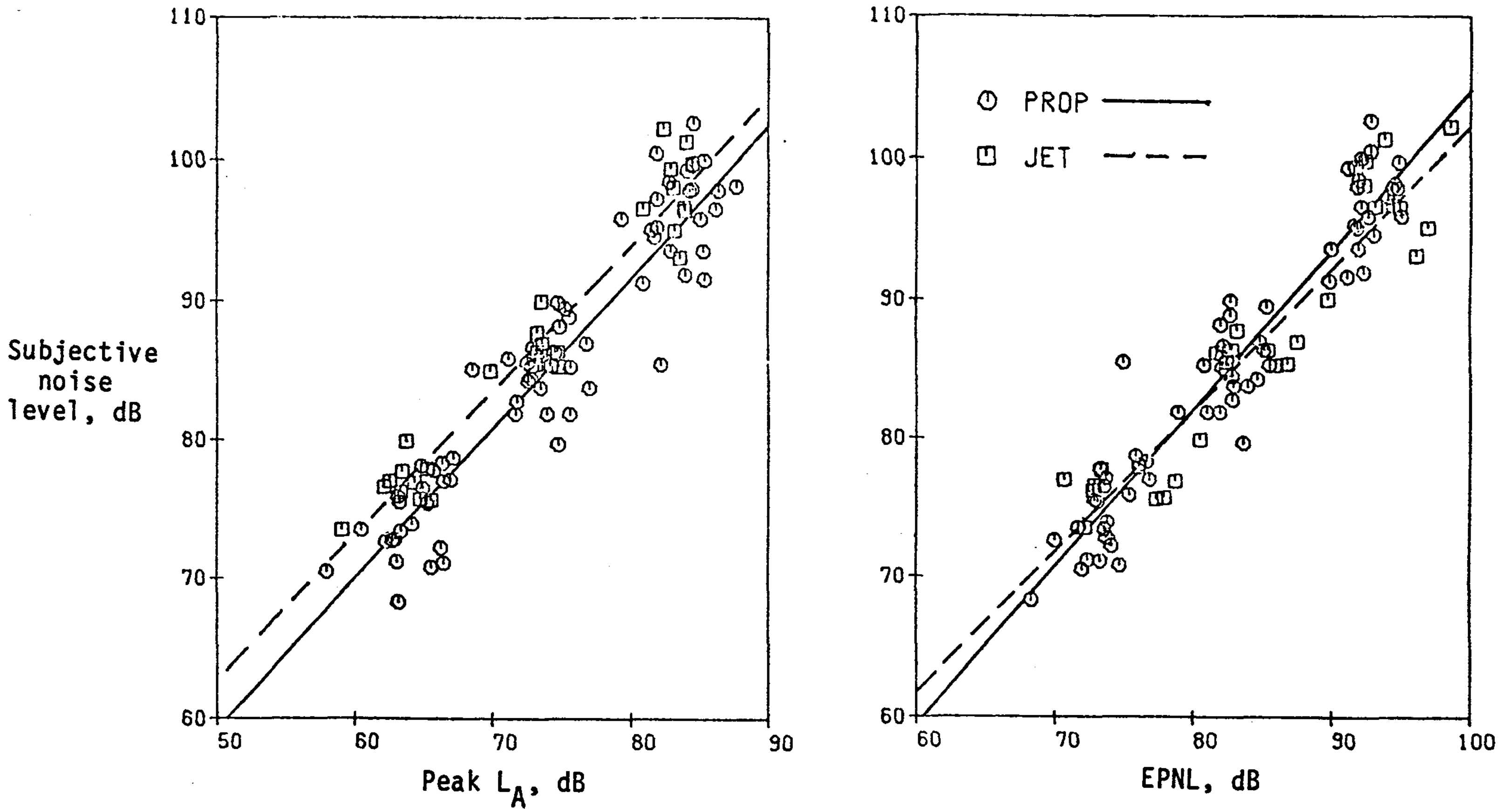

Figure 3.- Comparison between annoyance results for propeller airplanes and jet airplanes in the first experiment.

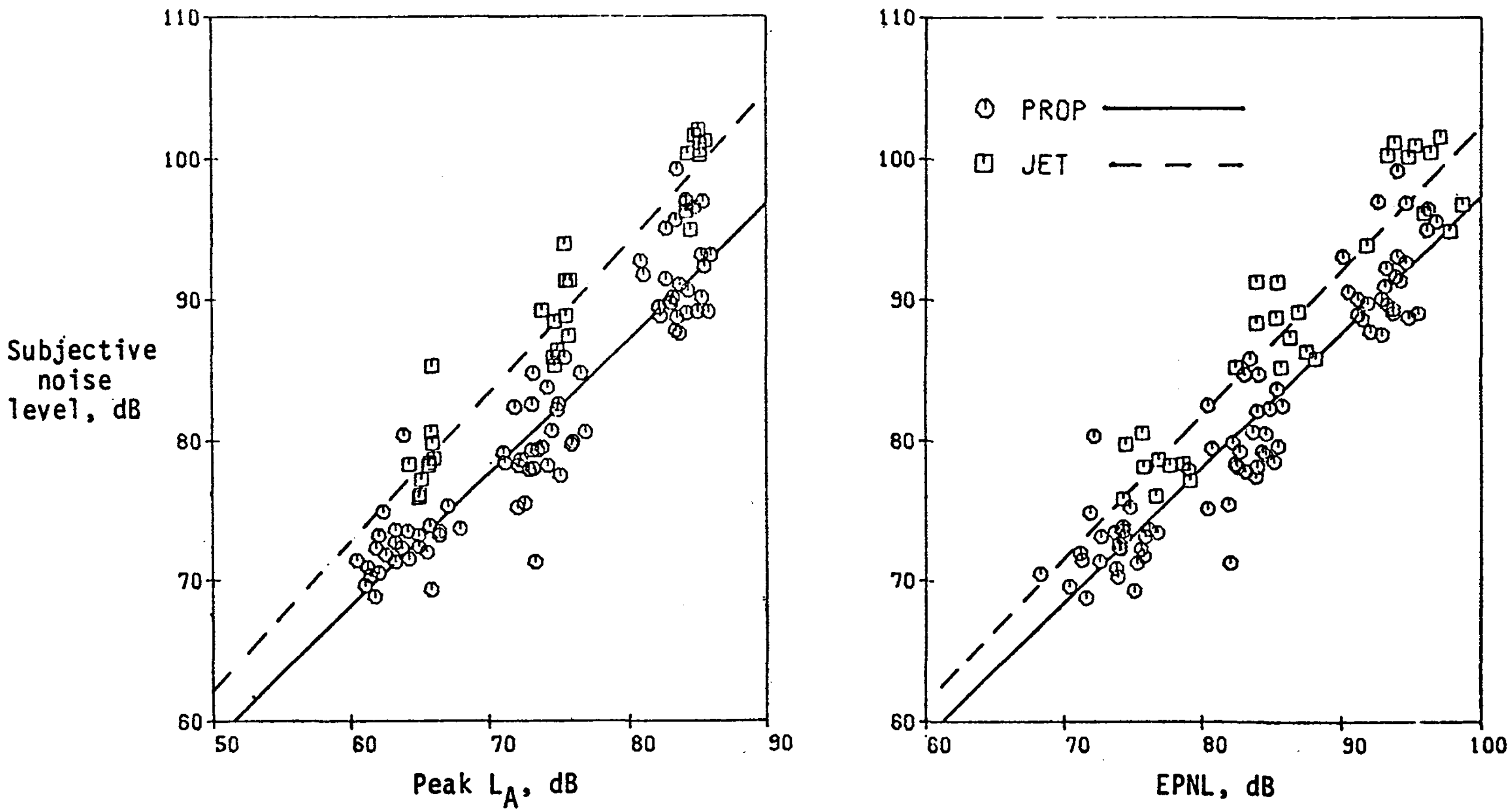

Figure 4.- Comparison between annoyance results for propeller airplanes and jet airplanes in the second experiment.

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15. Supplementary Notes

16. Abstract

Two laboratory experiments were conducted to examine the annoyance response of people to the noise of propeller airplane flyovers. The experiments were designed to provide information on the quantification of annoyance caused by propeller airplane noise. The specific items of interest were: (1) the annoyance prediction ability of current noise metrics; (2) the effect of tone corrections on prediction ability; (3) the effect of duration corrections on prediction ability; and (4) the effect of "critical band" corrections on the prediction ability of perceived noise level. This report presents preliminary analyses of the data obtained from the two experiments. The first experiment examined 11 propeller airplanes with maximum takeoff weights greater than or equal to 5700 kg. The second experiment examined 14 propeller airplanes weighing 5700 kg or less. Also included in each experiment were five different commercial service jet airplanes. Each airplane noise was presented at D-weighted sound pressure levels of 70, 80, and 90 dB to subjects in a testing room which simulates the outdoor acoustic environment. In each experiment the annoyance of each noise at each of the three levels was judged by 64 test subjects. Subjects judged 108 stimuli in the first experiment and 132 stimuli in the second experiment. Perceived noise level predicted annoyance better than A, D, or E-weighted sound pressure level. Corrections for tones greater than or equal to 500 Hz generally improved prediction ability for the heavier propeller airplanes. Tone corrections generally degraded prediction ability for the light propeller airplanes. Duration corrections improved prediction ability for the heavier propeller airplanes and degraded prediction ability for the light propeller airplanes. The effect on prediction ability of critical band corrections to perceived noise level varied between the two experiments and with other factors.

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