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VARIATION OF AIRCRAFT NOISE ANNOYANCE

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SUMMARY

A two-part investigation, consisting of laboratory and field tests, was conducted as part of a continuing program at Langley Research Center to account for the variability in annoyance response of people to aircraft noise. Earlier studies within this program found an increase in people's annoyance sensitivity to single event aircraft noise events between the beginning and end of testing. This change in sensitivity could be attributed to either a physiological time-of-day effect (i.e., a circadian rhythm) or simply to the total number of aircraft noise events experienced during the test period. In order to investigate the time-of-day factor, noise sensitivity measures (thresholds of annoyance to noise) were obtained from 96 subjects at home. These noise sensitivity measures were obtained with cassette tape recorders/headsets every 2 hours over a 24-hour period. The effect of number of aircraft noise events on noise sensitivity was investigated using the same subjects, but within the laboratory situation. In these tests, measures of sensitivity to noise were obtained from subjects before and after their exposure to varying numbers of aircraft noise events. The 24 hour data showed no evidence that noise sensitivity is physiologically cyclical. Consequently, these data cannot explain annoyance response variation to aircraft noise tests conducted during the daytime. However, the number of aircraft noise events did influence the subject's noise sensitivity. This effect completely accounts for the systematic increase in noise sensitivity during a laboratory test period.

INTRODUCTION

The effects of aircraft noise on subjective annoyance have been studied with both laboratory and community survey techniques (see ref. 1 for a review). Except for some emphasis upon the noise and number problem in field studies, the laboratory techniques are more often utilized to assess the importance of physical aspects of noise on annoyance for noise metric development and/or refinement. The rationale for this emphasis is the precise control of physical characteristics of noise within the laboratory that is not possible in field studies. However, laboratory studies (as do field studies) often result in restricted conclusions due to a large variation in annoyance responses provided by people to even a single aircraft noise. Relative to this response variation a recent investigation (ref. 2) indicated a systematic but unexplanable increase in the annoyance sensitivity of people to aircraft noise during a day of testing. Since subjects in these tests were not engaged in an activity, this effect could logically be attributed to either a physiological time-of-day effect, i.e., a circadian rhythm effect, or simply to the total number of aircraft noise events experienced during a test period. Either explanation has practical implications. The existence of a circadian rhythm effect would imply a physiological connection between annoyance response and the time of day. This type of information could lead to much more stable and accurate estimates of nighttime noise penalties, (i.e., day/night weighting factors, ref. 3), for estimation of community noise impact. On the other hand, an explanation of annoyance sensitivity change due to increase in the number of noise events would have implications for the manner in which laboratory results are used and interpreted. This effect could be extremely important for the interpretation of results of studies that involve limited control of noise presentation order, counter-balancing, etc. Consequently, the use of laboratory results for aircraft noise certification, land use planning, etc., would necessitate a close match between laboratory results and these applied problems.

The general objective of this investigation is to determine the basis for systematic individual annoyance response variability to aircraft noise. This overall objective can be divided into determining if annoyance sensitivity change during laboratory testing is due to a circadian rhythm type effect, or due to the total number of aircraft noise events experienced.

METHOD

Testing for each subject (12 subjects concurrently) involved four successive days of testing. The initial three days were designed for collection of field data to determine if subjective sensitivity to noise varies as a function of time of day. The final day of testing was conducted in the laboratory to determine if this noise sensitivity varies as a function of the number of aircraft noise exposures a person experiences. For these latter tests, measures of noise sensitivity were obtained prior and subsequent to exposure of various groups of subjects to different numbers of aircraft noise. Subsequent sections provide information as to the subjects, noise exposure equipment, noise stimuli, and test procedures associated with tests conducted in these two locations.

Subjects

A total of 96 paid volunteer subjects (12 males and 84 females) participated in the study. Their ages ranged from 19 to 58 years, with a median age of 32 years. All subjects were audiometrically screened and required to have standard normal hearing (ref. 4).

Noise Exposure Equipment

Field Equipment.- Commercially available cassette tape recorders and monophonic headsets were used to present 15 second duration bursts of broadband noise to subjects. Although the cassette recorders provide a relatively flat frequency response between 50 and 10,000 Hz, the headsets displayed some roll-off. The actual noises subjects heard are discussed in a subsequent section. The same noise was recorded for each tape recorder and the calibrations were completed with a phonic ear for each tape recorder and headset combination.

The cassette tape recorders were modified to assure that similar noises were produced with each set of equipment by disabling the tone control, volume control, and automatic record level and record capability.

Laboratory Test Facility.- The laboratory test facility used for presentation of noises to subjects was the exterior effects room (see fig. 1) of the NASA Langley Aircraft Noise Reduction Laboratory. Monophonic recordings of various noises were tape recorded and presented to subjects using 6 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.

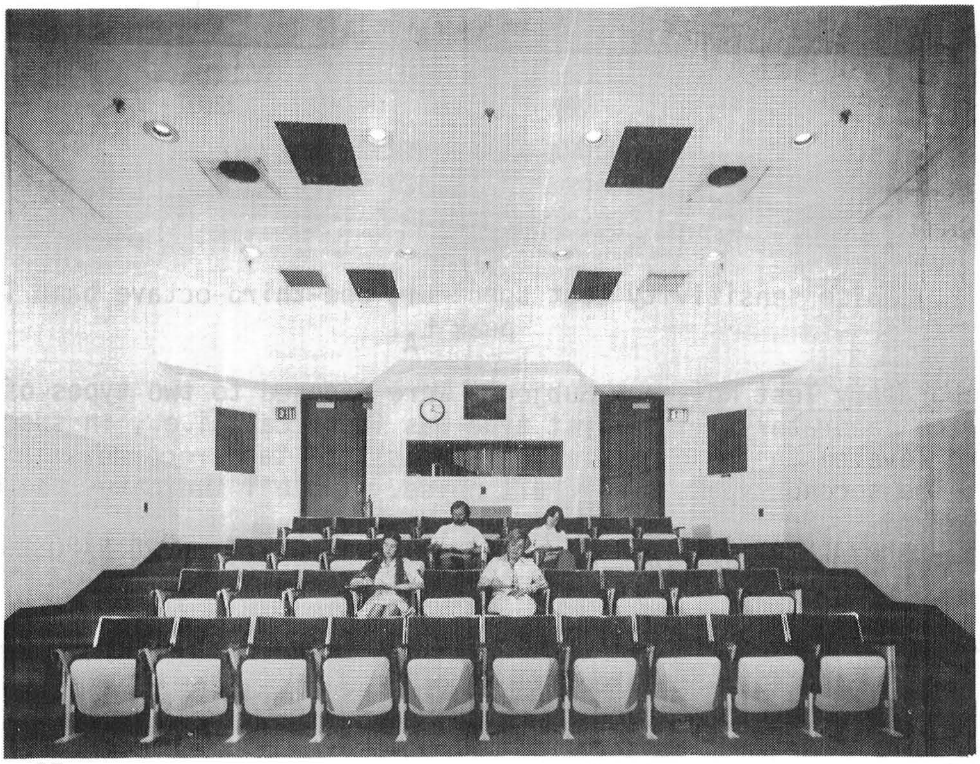

Figure 1.- Exterior Effects Room of NASA Langley Aircraft Noise Reduction Laboratory.

Noise Stimuli

Field Test Noises.- A subject was exposed to 20 noises during each testing period. Each of these noises had the same broadband frequency spectrum (see fig. 2) and lasted for a duration of 15 seconds. These noises ranged in a-weighted sound pressure level (measured with a phonic ear) from 65 to 85 db, in increments of 5 dB (giving a total of five noise levels). Through four randomizations (without replacement) of these five noise levels, a total of 20 noises were provided for each test period.

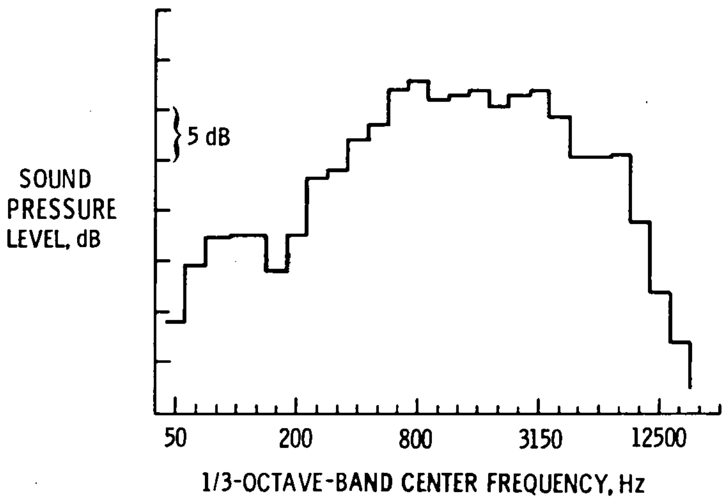

Figure 2.- Noise sensitivity test spectrum, one-third-octave band levels, at peak L_A.

Laboratory Test Noises.- Subjects were exposed to two types of noises within the laboratory. The first type was identical (i.e., in spectrum, duration and levels) to those used with the cassette tape recorders in the field tests. The second type was aircraft noise. Table 1 indicates the 8 different

Table 1.- SUMMARY OF THE AIRCRAFT NOISES THAT SUBJECTS WERE EXPOSED TO DURING A TEST SESSION.

Aircraft	Operation	A-Weighted Noise Level, dB
B-707	Takeoff	65
B-707	Landing	79
B-727-100	Takeoff	86
B-727-100	Landing	72
B-747	Takeoff	79
B-747	Landing	86
DC-8TJ	Takeoff	86
DC-8TJ	Landing	65
DC-8TF	Takeoff	72
DC-8TF	Landing	86
DC-9	Takeoff	65
DC-9	Landing	72
DC-10	Takeoff	79
DC-10	Landing	65
Concorde	Takeoff	72
Concorde	Landing	79

aircraft, each of takeoff and landing operations selected for this type of noise exposure. Four different a-weighted noise levels were randomly (4 times without replacement) assigned to the 16 aircraft noises of table 1. Successive test sessions represented additional randomizations of these same 16 aircraft noises. The same aircraft noises were selected for successive sessions in order to provide for constant L_{eq} per session.

TEST PROCEDURE

Field Tests.- A total of 3 days were allocated for field work. On the first day there was a single session at which the experimenter instructed the subject in the use of the cassette tape recorders and headsets. These instructions were provided so that subjects could obtain self-administrated measures of noise sensitivity on days 2 and 3. These noise sensitivity measures (ref. 2) were obtained using the method of constant stimuli in which the subject evaluated 20 successive 15-second duration noises of a test period as annoying or not annoying. The noise level evoking an annoyance response 50 percent of the time was taken as a measure of the individual's noise sensitivity. It is important to note that subjects were requested not to perform any other distracting activities during the testing.

Two different subject groups were used to investigate the time-of-day effects. An initial group of 72 subjects experienced 6 test periods during the daytime hours over which noise sensitivity had increased in laboratory studies. These test periods occurred at 8:00 a.m., 10:00 a.m., 12:00 noon, 2:00 p.m., 4:00 p.m., and 6:00 p.m. Testing for this group was intentionally restricted to daytime hours. This procedure was adopted so that any change in noise sensitivity could be attributed to time of day rather than heighten annoyance from being awakened during the night. Methodologically, all six test periods could be scheduled within 1 day. However, two test days were used for testing to counterbalance for the time of day at which testing started.

An important extension of this approach would be to collect such noise sensitivity information during evening/early morning hours. Consequently, an additional set of 24 subjects completed noise sensitivity tests at times of 6:00 p.m., 8:00 p.m., 10:00 p.m., 12:00 midnight, 2:00 a.m., 4:00 a.m., and 6:00 a.m. For these tests, subjects were scheduled for 2 nights of testing, with successive test period times scheduled on alternate nights. In this case, the block of test periods completed on the first and second day were counterbalanced. The logic for scheduling every other test period the same night was to reduce the burden on subjects.

Laboratory tests.- The fourth day of testing was conducted within the laboratory. Testing on this day consisted of obtaining noise sensitivity measures for each subject prior and subsequent to the exposure of subject groups to different numbers of aircraft noise. The instructions and noises provided to subjects to collect these noise sensitivity measures were identical to those used for the field tests. Between measures of noise sensitivity, subjects were exposed to either 2, 4, or 6 sessions of aircraft noise. Since there were 16 aircraft noises per session, different subjects were exposed to 32, 64 or 96 aircraft noises. Each aircraft noise was evaluated by a subject using an annoyance category scale with the end points labeled "zero annoyance" and "maximum annoyance." The scale was unipolar, continuous, and contained nine scalar points or demarcations.

RESULTS AND DISCUSSION

This section addresses the results and discussion related to the objectives provided in the introduction. The implications of these results are briefly discussed.

Time-of-Day Effects

The noise levels required for constant noise sensitivity at successive two hour intervals are shown in figure 3. There were no significant differences between the noise levels required for constant noise sensitivity from 8:00 a.m. to 10:00 p.m. Consequently, the horizontal straight line of figure 3 was based on an average of these levels to represent subject sensitivity during this time period. An important implication of these results is that the

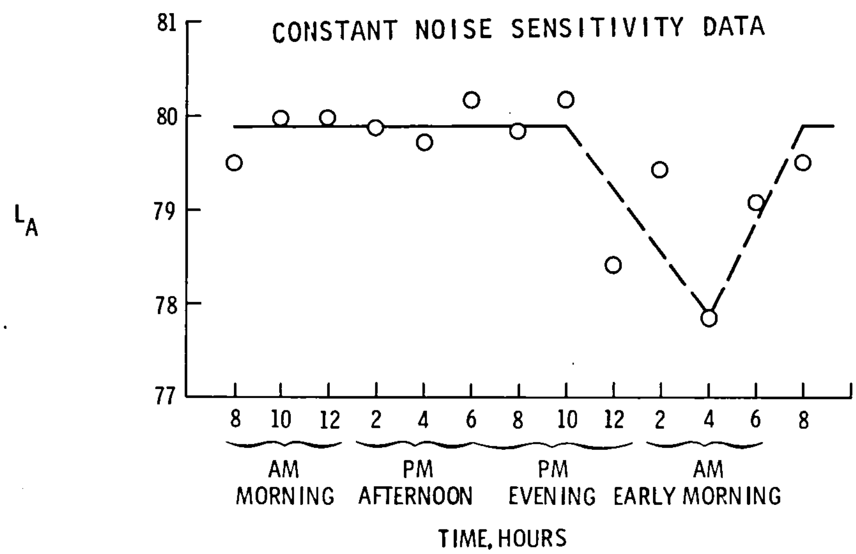

Figure 3.- Noise levels required for constant noise sensitivity as a function of time of day.

systematic variation in annoyance response that occurs during daytime laboratory studies cannot be attributed to a cyclical or circadian rhythm type effect of noise sensitivity.

A dashed line was used in figure 3 to represent the data trend between 10:00 p.m. and 6:00 a.m. for constant noise sensitivity, since the trend is not as clear as occurred earlier in the day. There was a significant decrease in noise levels needed for constant sensitivity between successive test periods of 10:00 p.m. and 12:00 midnight ($t = 2.81$, $df = 23$, $P < .05$), and 2:00 a.m., and 4:00 a.m. ($t = 2.16$, $df = 23$, $P < .05$), but not between 12:00 midnight and 2:00 a.m. There was, however, a significant ($t = 2.21$, $df = 23$, $P < .05$) increase of these responses between 4:00 a.m. and 6:00 a.m. The latter data trend probably indicates a return to a stable or asymptotic level for the daytime hours.

The data of figure 3 between 10:00 p.m. and 6:00 a.m. could possibly be curve fitted through different techniques. However, none of the alternatives would indicate a cyclical effect of noise levels needed for constant noise sensitivity across time of day of any practical importance. The maximum shift in noise level is 2 dB and only for a short time period. The implications of these results is that noise sensitivity is not connected with cyclical physiological behavior. It is important to remember, however, that in order to minimize the influence of activity interference on these responses, subjects were requested not to perform activities during testing. Therefore, results of this study do not preclude the possibility of a cyclical variation of noise sensitivity across time of day, especially if the measures are reflective of strong emotional attitudes resulting from activity interference (i.e., sleep disruption). In fact, these results indicate the need to base noise metric modifications to account for time of day upon research that systematically explores activity interference.

Number of Aircraft Noise Exposures

The effect of the total number of aircraft noise exposures on the noise level needed for constant noise sensitivity is shown in figure 4. The solid circles of figure 4 display $L_{A2} - L_{A1}$ (i.e., noise level of sensitivity subsequent to aircraft exposures minus noise level of sensitivity prior to aircraft exposures) as a function of the number of aircraft noise events experienced by a subject during testing. The horizontal line would represent the results if there was no change in noise sensitivity during a laboratory test. For comparative purposes, $L_{A2} - L_{A1}$ was computed (open circle of figure) using 253 subjects of a previous study (ref. 2). There was a significant decrease during testing in the noise levels needed for constant noise sensitivity for subjects exposed to 32, 64 and 96 aircraft noises ($t = 2.68$, 4.90, and 3.57 for 32, 64, and 96 aircraft noise exposures, respectively; $df = 23$, $P < .05$ in each case). An initial implication of these results is that a person's increase in noise sensitivity (i.e., decrease in noise level for constant noise sensitivity) within a laboratory investigation is a reliable phenomenon. This change of noise sensitivity is about 3 dB for a typical laboratory study that provides for 120 aircraft noise exposures to subjects. Consequently, these results account for the systematic change in the noise sensitivity of test subjects in an earlier study (ref. 2).

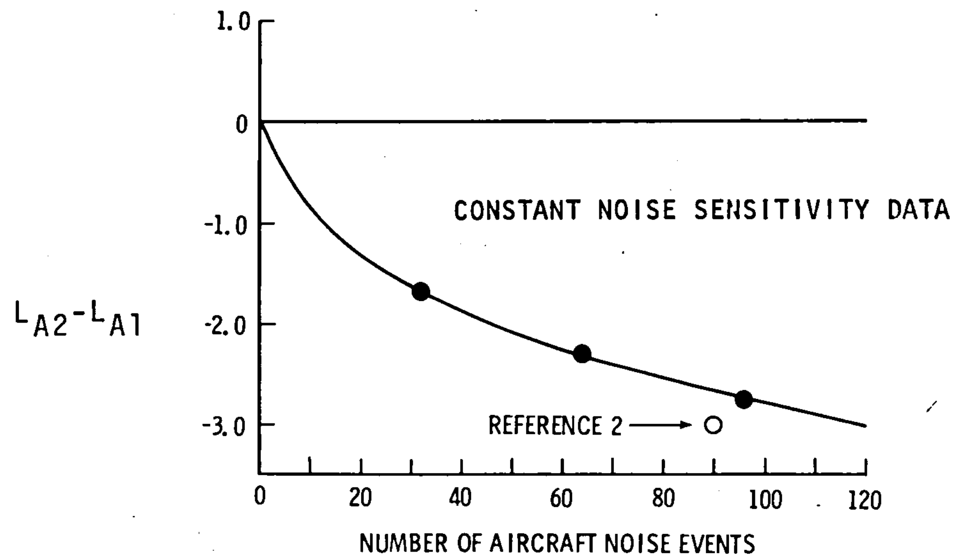

Figure 4.- Change in noise level (L_{A2} - L_{A1}) required for constant noise sensitivity between the beginning and end of testing, as a function of the total number of aircraft events experienced during testing.

Equation 5 of a previous study (ref. 2) for predicting annoyance responses to aircraft noise provides a mathematical basis for interpretation of this data. This equation was stated as:

$$AR = 3.43 + .18 \left(TS - \frac{1}{2} AA\right)$$

where

AR = annoyance response to an individual aircraft noise

TS = test stimulus or individual aircraft noise measured in units of -weighted noise level, dB

AA = noise sensitivity (referred to as aircraft adaptation level in ref. 2) measured in units of a-weighted noise level, dB

This equation provides a mechanism to establish the trading relationships between noise level of aircraft and noise sensitivity of a subject needed for constant annoyance to aircraft noise. For example, consider that one person with a noise sensitivity of 65 provides an annoyance response of 2.0 to an aircraft noise. That same aircraft noise has to be increased in noise level by 5 dB for a person with a noise sensitivity of 75 to provide an annoyance response of 2.0. Relative to the current study, this same equation can be used to interpret the effect of number of aircraft noises on annoyance response. For illustrative purposes, consider an experiment which provides for exposure of 120 aircraft noises to subjects in which the first and last aircraft noise are identical. Based on results of the present study, 120 aircraft noise exposures would increase noise sensitivity about 3 dB. Thus, with equation 5 it can be concluded that an aircraft noise would need to be decreased in noise level 1.5 dB at the end of testing to receive the same annoyance evaluation as at the start of testing. Despite the small magnitude of this noise level, it is important due to the systematic nature of the effect. In fact, this effect may explain a portion of the discrepancy between results of different studies. Probably most important from a methodological point of view is the fact that aircraft noise comparisons could be biased and/or misleading if the comparison are derived from studies with presentation order limitations.

CONCLUDING REMARKS

Several conclusions can be derived about the sensitivity of people to noise. These conclusions include: (1) There is no evidence that noise sensitivity is physiologically cyclical or time-of-day dependent; the slight increase of noise sensitivity between 10:00 p.m. and 4:00 a.m. is not of practical value for modification of day/night noise metrics, and (2) The increased noise sensitivity of a person during a laboratory investigation is a reliable phenomenon and directly related to the number of noise exposures; there is a 3 dB increase in noise sensitivity for a person during a typical experiment which includes 120 aircraft noise exposures.

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16. Abstract
Laboratory and field studies were conducted to determine the basis for increased sensitivity of people to noise during aircraft noise studies. This change in sensitivity could be attributed to either a physiological time-of-day effect (i.e., a circadian rhythm) or simply to the total number of aircraft noise events experienced during a laboratory test period. In order to investigate the time-of-day factor, noise sensitivity measures were obtained from subjects at home with cassette tape recorders/headsets over a 24-hour period. The effect of number of aircraft noise events on noise sensitivity was investigated within a laboratory. In these tests, measures of sensitivity to noise were obtained from subjects before and after their exposure to varying numbers of aircraft noise events. The 24-hour data showed no evidence that noise sensitivity is physiologically cyclical. Consequently, these data can not explain annoyance response variation to aircraft noise tests conducted during the daytime. However, the number of aircraft noise events did influence the subject's noise sensitivity. This effect completely accounts for the systematic increase in noise sensitivity during a laboratory test period.

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