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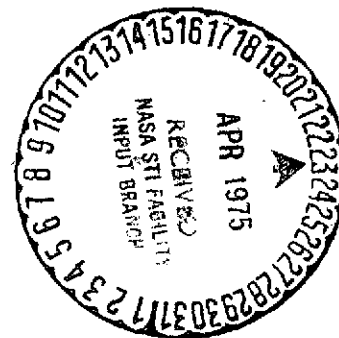
EFFECTS OF THREE ACTIVITIES ON ANNOYANCE  
RESPONSES TO RECORDED FLYOVERS

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## EFFECTS OF THREE ACTIVITIES ON ANNOYANCE

### RESPONSES TO RECORDED FLYOVERS

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#### ABSTRACT

Subjects participated in an experiment in which they were engaged in TV viewing, telephone listening, or reverie (no activity) for a 1/2-hour session. During the session, they were exposed to a series of recorded aircraft sounds at the rate of one flight every 2 minutes. Within each session, four levels of flyover noise, separated by 5dB increments, were presented several times in a Latin Square balanced sequence. The peak level of the noisiest flyover in any session was fixed at 95, 90, 85, 75, or 70 dBA. At the end of the test session, subjects recorded their responses to the aircraft sounds, using a bipolar scale which covered the range from "very pleasant" to "extremely annoying." Responses to aircraft noises were found to be significantly affected by the particular activity in which the subjects were engaged. Furthermore, not all subjects found the aircraft sounds to be annoying.

#### INTRODUCTION

Interference with TV viewing is a major aircraft noise-related problem of airport community residents (ref. 1). Williams, Stevens, and Klatt (ref. 2) used a 10-point rating scale to obtain judgments of the acceptability of individual aircraft flyover noises while subjects either watched television or did not watch television. The ratings with or without TV viewing were almost

identical. Langdon and Gabriel (ref. 3) conducted a series of experiments in which subjects watched videotaped television programs and, at the end of each period, rated the acceptability of the total noise exposure during that period. In these experiments, noise level was found to produce "significantly" less effect than predicted by the Williams, Stevens, and Klatt (ref. 2) data. The authors concluded further that "there is, however, almost certainly some positive effect, which contradicts a pure masking hypothesis." Given, however, the number of subjects per group and 95 percent confidence limits of about one unit, it is difficult to accept this conclusion without a test for significance. There is no obvious effect of level on acceptability which can be seen in their Experiments I and II data.

A model of human response to aircraft noise was recently developed by Gunn and Patterson (see Appendix A). This dynamic stress-reduction model predicts, among other things, that subjects engaged in different activities, when exposed to the same aircraft noise environment will respond with differing degrees of expressed annoyance. In order to test this hypothesis and learn the extent to which the specific activity engaged in effects one's annoyance reaction to aircraft noise, a laboratory experiment was performed as a part of a joint NASA/ Memphis State University research program and is described in this report.

## PROCEDURE

### Subjects

Subjects were 324 members of the university community at Memphis State University. All were screened for normal hearing and those with HL greater than 20 dB (ISO) were excluded from the study. Hearing of subjects was

evaluated by a graduate student in audiology at the Memphis Speech and Hearing Center. Subjects were paid for their participation in this experiment.

#### Method

The 324 subjects were randomly divided into three groups of 108. Each of these groups were exposed (in subgroups of 6) to 1/2-hour of recorded aircraft landing noises. At the end of the 1/2-hour session, subjects were asked to indicate their general response to the aircraft sounds they had heard. The first group (reverie group), which was comprised of 18 subgroups of 6, simply sat and listened to the aircraft noises. The second group watched a preferred TV show during exposure to the aircraft noise and the third group listened to a recorded Modified Rhyme Test over a telephone during the aircraft noise exposure. In short, three groups of subjects were exposed to recorded aircraft noises and made judgments of annoyance at the end of the 1/2-hour session. The only difference in conditions between the three groups was the activity in which the subjects were engaged during the exposure to the aircraft noises. Table 1 shows the test sequence for each of the three groups.

#### Reverie

Subjects were ushered into the test room and seated. Seats were arranged before a loudspeaker so that the noise exposure would be equivalent for all subjects who were then left to themselves for a period of 15 minutes. This time was needed to provide a uniform experimental situation compared to the other two activities. Talking was permitted in this pretest period. Near the end of the 15-minute period, the experimenter reentered the room and read the instructions given in Appendix B. After this, the experimenter left the room

and a tape recording of aircraft flyover sounds was activated. The same aircraft recording was used during all three activities. These flyover sounds and the method of presentation are described in the Apparatus and Stimuli sections of this report. At the end of the experimental session, the experimenter entered the room and distributed copies of the response sheet which is shown in figure 1. The scale used was bipolar and subject responses were not biased by the use of plus or minus signs at either end of the scale. Similarly, the flyover stimuli were never described as "aircraft noises" but rather as "aircraft sounds."

#### TV Viewing

Subjects were ushered into the test room and seated in an arc before a color television set. The TV set was situated in front of the loudspeaker mentioned previously, as it was in the no-task condition. These subjects had earlier indicated that the program they were about to watch was one of their favorite programs. The TV set was turned on and the subjects were read the instructions shown in Appendix C and the TV audio volume control was adjusted to a level acceptable to all subjects. Two minutes prior to the beginning of the program, the subjects were read the instructions shown in Appendix B. The TV set was then turned on to the selected program and the experimenter left the room. The aircraft flyover noise tape was immediately activated at the beginning of the TV program. After the last aircraft flyover in this session, the television set was left on so as not to cause changes in subjects' annoyance that would be unrelated to the flyover sounds. The experimenter quietly distributed copies of the response sheet shown in figure 1 and indicated that they were to complete this form according to the written instructions. After all subjects had completed this response form, the experimenter collected them and distributed copies of the response form shown in figure 2.

## Telephone Listening

Prior to the beginning of this phase of the experiment, a pilot study was conducted with several listeners to determine the playback levels that would be required to achieve an average of about 90 percent correct on the speech interference tests, in quiet. This was done so that performance on the tests would be degraded even further during simulated aircraft flyovers. It must be remembered that the measure of primary concern here was annoyance related to the interference with telephone use, not speech intelligibility, per se. It was necessary to use an intelligibility test to provide a device that would hold subjects' attention to verbal stimuli.

Subjects in this phase of the study were ushered into the test room and seated. Beside each seat was a telephone handset. The subjects heard the instructions shown in Appendix D. The first instruction was read to the subjects by the experimenter. The second instruction was tape recorded and given to the subjects over the telephone handsets. Following these recorded instructions, the experimenter read to the subjects the instructions shown in Appendix B. (These latter instructions were read to all subjects in each phase of the experiment, thus providing maximum uniformity in instructions.) The experimenter then left the room and the recorded speech and aircraft noise stimuli were presented.

Six lists of the Modified Rhyme Test (MRT) as developed by House, et al., 1963 (ref. 4) were presented to subjects. The answer ensembles in these tests consist of six words each with a total of 50 ensembles per test. Prior to tape recording the tests, the correct word from each ensemble was selected by

use of a table of random numbers. The tests used are shown in Appendix E. The recorded test word is underlined in each ensemble. Subjects' response forms were identical to the lists shown in Appendix E, except that no words were underlined, of course. Subjects were required to draw a line through the correct word in each ensemble per the instructions given in Appendix D. At the end of the experimental session, the experimenter collected the speech test response forms and distributed copies of the response form shown in figure 1. These forms were then completed by the subjects and collected by the experimenter.

### Apparatus

The apparatus used in this experiment is shown in block diagram form in figure 3. During the TV viewing and reverie conditions, the speech track was disconnected at the tape recorder. The voltmeter was used to set noise and speech levels prior to each experimental session. The color TV set was positioned in front of the Klipschorn speaker in such a way that it did not significantly block the sound output from the speaker during presentation of aircraft flyover sounds. The test room was a 15 x 24 ft room furnished to resemble a living room. Ambient noise level in the room was 43 dBA as determined with a sound level meter set on slow reading position.

### Stimuli

Aircraft noise.- Each subgroup of subjects was exposed to a 1/2-hour duration playback of recorded Boeing 747 landing sounds at the rate of one overflight every 2 minutes. In order to make the noise exposure a little more realistic, the peak levels of the individual flyover noise were varied from one overflight to the next. Within any session, there were four peak levels of aircraft noise, designated A, B, C, and D. There were 16 overflights during



each 30-minute session and there were four overflights at each level A, B, C, and D, in a balanced Latin Square sequence. Table II shows the corresponding sound levels for each peak flyover level and figure 4 shows a plot of noise level, in dBA, versus time. For each activity, the aircraft noises, in general, were presented at six intensities, designated "Intensity 1, 2, 3, 4, 5, 6." As can be seen by inspection of Table II and figure 4, the most intense aircraft sound in intensity 1 is 70 dBA peak and the other peak levels within that session decrease to 55 dBA in 5 dB increments. Likewise, in intensity 2, the most intense aircraft sound is 75 dBA and the quietest is 60 dBA, and so on.

Speech stimuli.- The experiment involved the presentation of speech as well as aircraft flyover sound stimuli. The same flyover stimuli were presented during all three activities, i.e., reverie, TV viewing, and telephone listening. Controlled speech stimuli were presented only during the telephone listening phase of the experiment. The two sets of stimuli (aircraft and speech) were recorded on two tracks of a single tape. This provided synchrony between the speech and flyover stimuli. The speech stimuli were recorded in a commercially available sound treated room by a speaker of general American English. Speech stimuli were recorded at the rate of approximately one word every 6 seconds. The test word was appended to the phrase; "number \_\_\_\_\_ is \_\_\_\_\_," where the last blank corresponds to the position of the test word. The talker monitored his voice level with a VU meter during recording of speech stimuli. Speech stimuli were recorded on one tape track on a high quality audio tape recorder with a commercially available dynamic microphone. The recorded speech material is shown in Appendix E. Speech stimuli were played to listeners at constant level such that the speech peaks were approximately 50 dBA in the telephone handsets as measured in a 6cc coupler.

The aircraft flyover stimuli were recorded on the second track of the tape. The two tracks were juxtaposed so that the first word of the speech stimuli and the beginning of the first flyover occurred at about the same time. Flyover levels were calibrated in the test room using a sound level meter. A corresponding voltage for a calibration tone on the tape was observed and recorded. These voltages were used in subsequent sessions to set the correct flyover levels. These calibrations were checked periodically during the experiment to insure consistency of stimuli presentation. A diagram showing the level of stimuli presented to subjects and the activity they were performing is shown in Table III.

Stimuli analysis.- The aircraft flyover sounds were recorded as they occurred in the test room using commercially available acoustic analysis recording equipment. The sounds were recorded at the extreme levels of 95 and 70 dBA at several seat positions normally used by subjects. In addition, a recording of the speech signal was made with one of the handsets coupled to the microphone while the aircraft flyover sounds emanated simultaneously from the loudspeaker. These recorded stimuli will be analyzed at a computer facility and results will be available sometime in the near future for a more detailed analysis of the relationships between actual speech interference and the physical description of the noise.

## RESULTS

Figure 5 shows the median annoyance scores versus session intensity level for each activity in which S's were engaged during the aircraft noise exposure. The three regression lines were significantly different from each other, i.e., the slope of the "telephone listening" line was significantly ( $p < .05$  by t test)

different than the slopes of the "TV Viewing" and "Reverie" regression lines and median values of the "TV Viewing" regression line differed significantly ( $p < .05$  by median test) from those of the "Reverie" regression line. Median tests of the differences of annoyance at each session intensity show that annoyance resulting from noise interruption of TV viewing at intensity 1 was significantly ( $p < .05$ ) greater than that for either "Reverie" or "Telephone Listening," while at intensity level 5, the relation is reversed for "TV viewing" and "telephone listening." That is to say, in the session in which the loudest aircraft noise was 70 dBA peak, those subjects viewing TV expressed greater annoyance than those listening to speech stimuli on the telephone or those engaged in reverie (no task). As the aircraft noise intensity increased to the point where the loudest aircraft sound was 90 dBA peak, the annoyance of those engaged in the telephone listening task grew to the point where it was significantly greater than the annoyance of those engaged in the other two tasks.

Table IV shows the frequency distribution of annoyance scores for all intensity levels and activities. Note that 17 subjects (over 5 percent of the 324 who participated in this experiment) reported that the aircraft sounds were "pleasant" to hear.

#### DISCUSSION

The results suggest that the "telephone listening" task provides a much more sensitive indicator of peoples' overall annoyance response to aircraft noise than either "TV viewing" or "reverie" situations. While on the surface the results might at first seem to be at variance with past studies which show fairly high correlations between noise level and the resulting annoyance reaction

in the no-task situation, careful consideration of the procedures and conditions of this experiment makes the results of this study more understandable. To begin with, it is widely known that laboratory subjects judging the loudness or noisiness of individual noises covering a given intensity range will quite neatly order the stimuli as an increasing monotonic function of the intensity level, clearly demonstrating that they can discriminate intensity levels, if nothing else. Note, however, that the subjects in these experiments made only one judgment of the effect of a 1/2-hour exposure to aircraft noises presented at various intensity levels at the rate of about one flight every 2 minutes. The experimental situation was contrived such that the subjects were not required to discriminate one intensity from another, but rather that they were to report their reactions to one specific exposure condition. This is not to say that the subjects did not use a standard against which to compare their reactions to the experimental stimuli. They could, conceivably, have an existing internal standard developed from real life experiences against which to compare the integrated effects of the laboratory noise exposure. The practice of obtaining only one response from each subject has much in common with the assessment of individual reactions of airport community residents to their own neighborhood noise environment. It is common practice in social surveys dealing with community response to aircraft noise to ask individuals to rate their own noise environment on various numerical category scales. In such studies, the respondents are not usually asked to rate more than one noise environment, their own. It is not surprising, therefore, that most such studies have found rather poor correlations between noise levels in the environment and reported annoyance reactions. It is clear from our data that the growth and absolute level of annoyance differ depending on which specific activity is interrupted by the intruding aircraft noise. With reference to the stress-reduction model of Appendix A, the data support the hypothesis that reaction to noise is modified

by the nature of the activity engaged in at the time of the noise. A viable predictor of annoyance reaction to aircraft noise must then account for the "dominant" activity in a given community during each noise exposure period. It would not be surprising to find in future experiments still another (and totally different) psychophysical function relating annoyance and noise level which occurs during and possibly interrupts sleep. The same could be said for the reactions of people engaged in various other activities. While both our TV viewing task and telephone listening task involved aural communications, the telephone listening task differed in a number of important ways. Firstly, there was no redundancy built into the speech test presented over the telephone while there is a certain amount inherent in the usual TV show. Secondly, the importance of speech intelligibility was artificially increased in the telephone listening task by offering a bonus for superior speech reception scores. The differences in annoyance during TV viewing and reverie suggest a possible different basis for the annoyance reaction in each situation. One might speculate that the significantly greater annoyance reported by the TV viewers in intensity level 1 (where the loudest overflight was only 70 dBA peak) may have been due to distraction, rather than communication interference from masking, per se.

#### CONCLUDING REMARKS

It is concluded that the results of this experiment support the Gunn/Patterson Stress Reduction Model in that the degree of annoyance experienced by people exposed to aircraft noise depends upon the nature of the specific activity in which they are engaged at the time of the noise exposure. The finding that some laboratory subjects, over 5 percent, find the aircraft noises to be somewhat pleasant indicates the need for a closer look at the validity of

laboratory studies, especially those in which subjects are required to respond on a unipolar scale of annoyance which does not allow for the possibility of some subjects who find the noises, at least in a laboratory setting, to be pleasant to hear. The speech communication task appears to be the most sensitive procedure for the laboratory assessment of the effects of different levels of aircraft noise exposure.

#### REFERENCES

1. Galloway, W. J.; and Bishop, D. E.: Noise Exposure Forecasts, Evolution, Evaluation, Extensions, and Land Use Interpretations. Bolt Beranek and Newman, Inc. Tech. Rep. FAA-NO-70-9, 1970.
2. Williams, C. E.; Stevens, K. N.; and Klatt, M.: Judgments of the Acceptability of Aircraft Noise in the Presence of Speech. J. Sound Vib., vol. 9, 1969, pp. 263-275.
3. Langdon, L. E.; and Gabriel, R. F.: Judged Acceptability of Noise Exposure During Television Viewing. J. Acoust. Soc. Am., vol. 56, 1974, pp. 510-515.
4. House, A. S.; Williams, C.; Hecker, M.; and Kryter, K.: Psychoacoustic Speech Tests: A Modified Rhyme Test. TDR No. ESD-TDR-63-403, Decision Sciences Laboratory, U. S. Air Force.

TABLE I - TEST SEQUENCE

15 MINUTES	30 MINUTES	5 MINUTES	5 MINUTES
Reverie (no task)			
S's sit and talk freely, Instruction "A" read to S's	S sits; talking not permitted	S's complete Data Sheet 1	
TV Viewing			
TV audio adjusted and instructions "B" and "A" read to S's	S views TV program previously selected	S's complete Data Sheet 1	S's complete Data Sheet 2
Telephone Listening			
Instruction "C" and practice given to S's; then instruction "A"	S listens to telephone for speech reception test	S's complete Data Sheet 1	

TABLE II - PEAK AIRCRAFT FLYOVER LEVEL IN dBA

Stimulus Designator	Session Intensity Level					
	1	2	3	4	5	6
A	70	75	80	85	90	95
B	65	70	75	80	85	90
C	60	65	70	75	80	85
D	55	60	65	70	75	80



TABLE III - SUBJECT ASSIGNMENTS

	Session Noise Intensity Level					
	1	2	3	4	5	6
Peak Level of Most Intense Aircraft Noise During Exposure, in dBA	70	75	80	85	90	95
Activity						
No Task	S1-S18	S19-S36	S37-S54	S55-S72	S73-S90	S91-S108
TV Viewing	S109-S126	S127-S144	S145-S162	S163-S180	S181-S198	S199-S216
Telephone Listening	S217-S234	S235-S252	S253-S270	S271-S288	S289-S306	S307-S324

TABLE IV - FREQUENCY DISTRIBUTION OF SCORES

Very Pleasant		Neutral					Extremely Annoying				Subject Response Scale		
-5	-4	-3	-2	-1	0	1	2	3	4	5	Median	Condition	
				3	5	6		2	2		.67	70 Rev	
					4	4	2	6	1	1	2.0	75 Rev	
		1		1	2	1	2	2	2	1	1.2	80 Rev	
1			2		1	6		2	5	1	1.3	85 Rev	
	1	1			3	3	5	5			1.7	90 Rev	
				1	4	1	1	4	1		1.93	95 Rev	
					2	3	4	7	2		2.50	70 TV	
				1			3	8	4	2	3.12	75 TV	
					3	1	3	4	3	4	3.0	80 TV	
				1	2	4	4	2	3	2	2.0	85 TV	
							4	2	5	3	2.9	90 TV	
							2	2	7	3	3.21	95 TV	
		1	1		9	1	2	2	1		0.2	70 Tel	
		1			1	5	5	2	1	3	1.9	75 Tel	
					1	1	4	8	3	1	2.87	80 Tel	
							2	4	7	1	4	2.93	85 Tel
							1	1	3	6	7	4.17	90 Tel
							1	4	4	4	5	3.5	95 Tel

PLEASE INDICATE YOUR GENERAL REACTION TO THE AIRCRAFT SOUNDS WHICH WERE PRESENTED DURING THE SESSION BY PLACING A CHECK MARK NEXT TO THE APPROPRIATE POINT ON THE SCALE SHOWN BELOW.

<input type="checkbox"/>	5	↑ EXTREMELY ANNOYING  NEUTRAL  ↓ VERY PLEASANT
<input type="checkbox"/>	4	
<input type="checkbox"/>	3	
<input type="checkbox"/>	2	
<input type="checkbox"/>	1	
<input type="checkbox"/>	0	
<input type="checkbox"/>	1	
<input type="checkbox"/>	2	
<input type="checkbox"/>	3	
<input type="checkbox"/>	4	
<input type="checkbox"/>	5	

Figure 1.- Subject response sheet 1.

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CHECKING THE APPROPRIATE BOX.

- HOW WOULD YOU RATE THE TV SHOW YOU WATCHED?  
 EXCELLENT     GOOD     FAIR     POOR
  
- HOW WOULD YOU RATE THE TV SOUND LEVEL?  
 TOO QUIET     JUST RIGHT     TOO LOUD
  
- WHAT BOTHERED YOU THE MOST ABOUT THE AIRCRAFT SOUNDS? (WRITE A FEW WORDS TO DESCRIBE YOUR FEELINGS.)

Figure 2.- Subject response sheet 2.

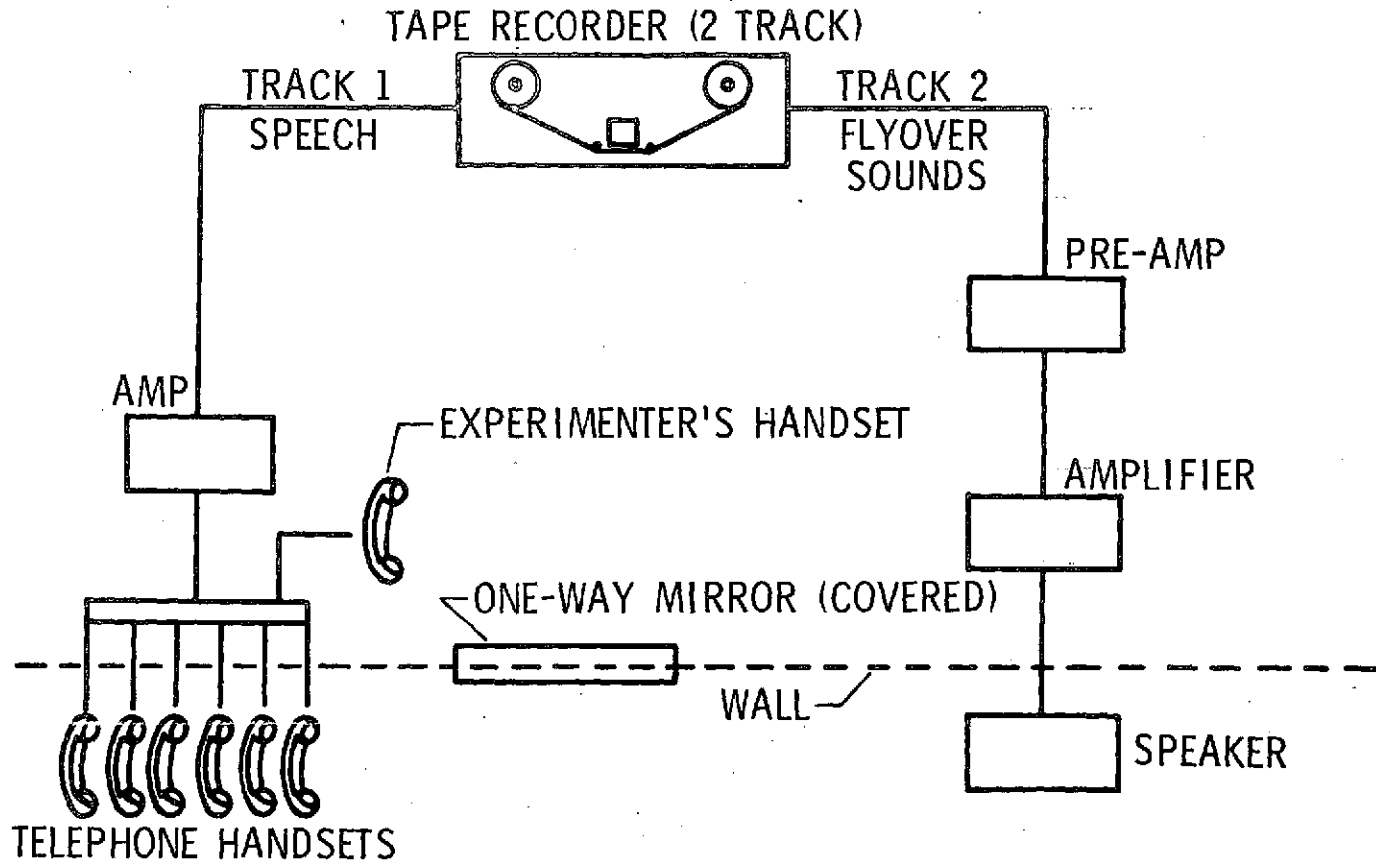


Figure 3.- Apparatus.

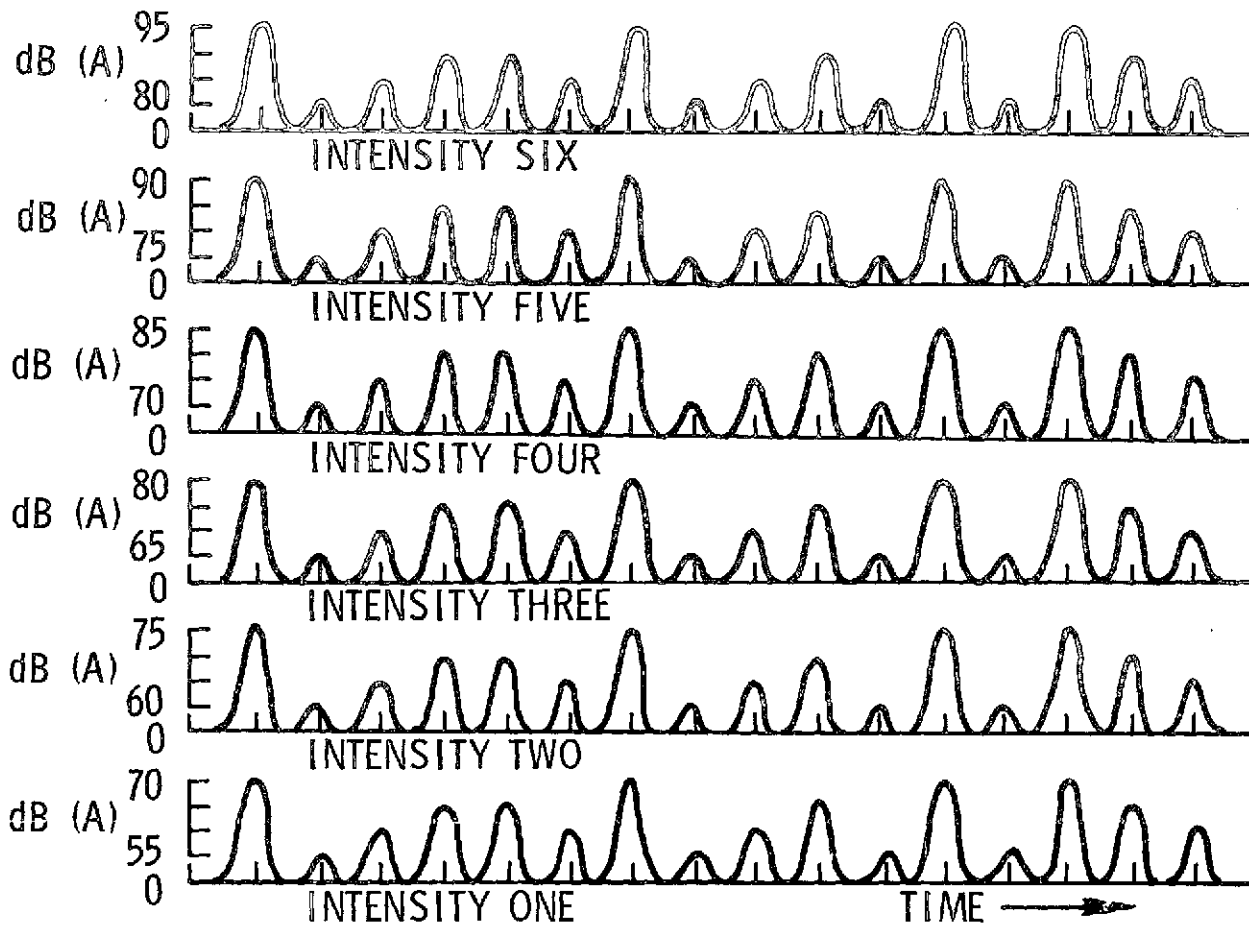


Figure 4.- Aircraft flyover noises.

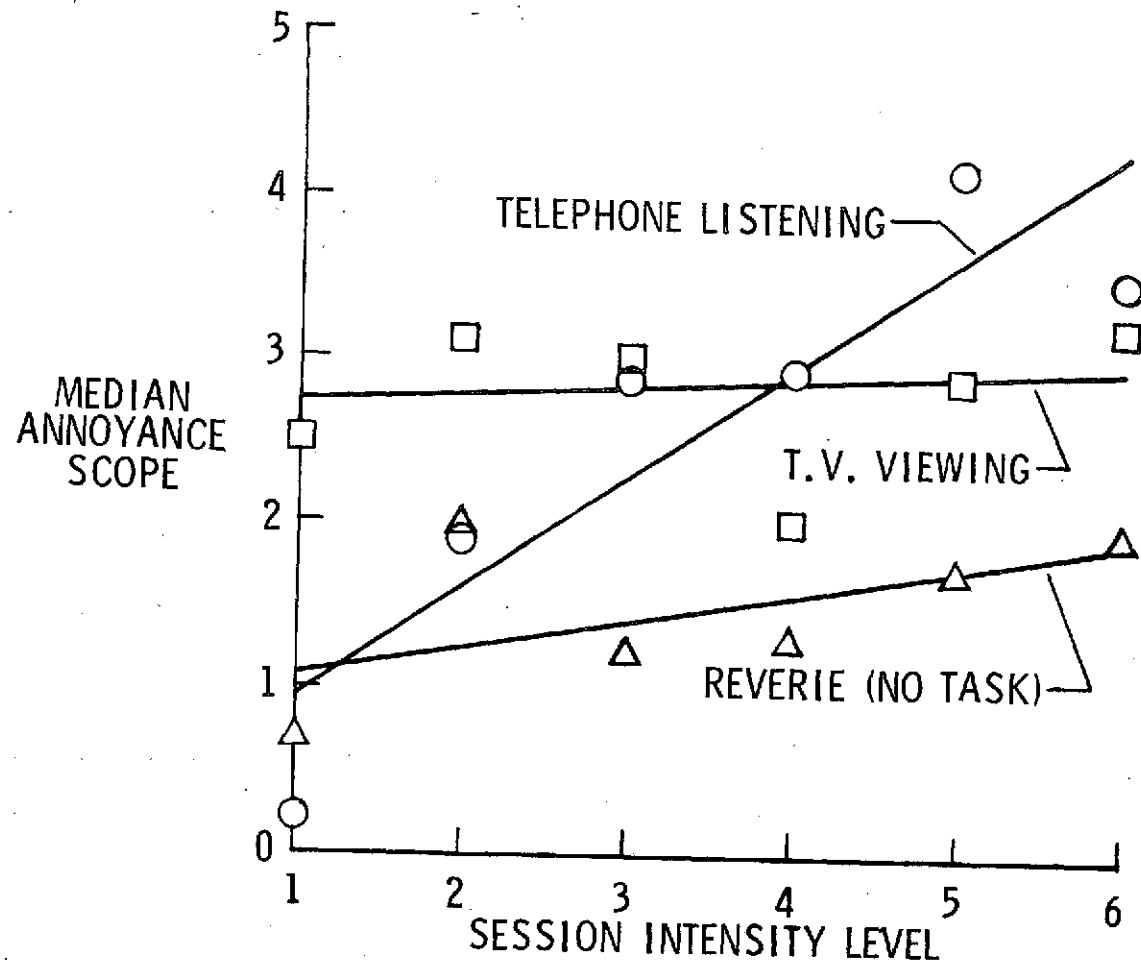


Figure 5.- Effects of activity interruption

APPENDIX A

THE GUNN/PATTERSON STRESS REDUCTION MODEL

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In the development of a methodology for the assessment of community response to aircraft noise, an important concern is the identification of specific measurable changes exhibited by the exposed community. Following this, the psychophysical relationships between the cause (noise) and effect (community response) need to be determined. To increase the meaningfulness of the predicted response, relationships between response categories should also be determined. For example, if the mean annoyance of a given community is 4.8 (on a scale of 6) and this is designated as "very annoying," very little information regarding the actual state of mind of the average community resident is known. If, however, the relationship between annoyance, desire to move out of the neighborhood, health effects, sleep loss, hearing loss, activity interruption, and degradation of the perceived quality of life are predictable from knowledge of the degree of annoyance, for instance, then the information becomes considerably more meaningful to the various users, such as aircraft designers, airport operators, pilots, legislators, and public administrators.

Some of the specific measurable changes exhibited by airport community residents resulting from aircraft noise can be determined by answers to questions in social surveys, while certain behavioral changes can be directly observed or traced through official records, such as those of the telephone company, real estate offices, and hospitals. However, a specific model of individual reaction to aircraft noise is needed in order to determine better which specific changes may be anticipated and how they can be measured.

The initial attempt at formulation of a model\* is shown in figure A1. This model is based upon the premise that individuals will attempt to reduce,

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\*The Stress Reduction Model was developed by W. J. Gunn of NASA, Langley Research Center and H. P. Patterson of Tracor, Inc.

avoid, or eliminate stress in their lives. Stress may be defined here as a general state of physical or psychological unrest. The model suggests that aircraft noise is perceived within two general contexts: situational and human factors. That is, qualities of the individual's physical, social, and psychological environments are important in his perception of the noise.

Only when the perception is "filtered" through the various meanings associated with the noise, through the interruption of activities and/or through evaluations of the aversive nature of the noise per se, is stress produced. The stress is manifested primarily in the development of negative feelings about the noise and in health problems. However, the individual will make every attempt to relieve this stress. Two methods are shown: overt behavior and internal adjustment. Overt behavior may be of various types, including complaint, retreating indoors or out of the neighborhood, and soundproofing the home. Internal adjustment is seen in adaptation, habituation, rationalization, and resignation to the noise. It is important to note that individuals who do not or cannot take overt action or who do not or will not make internal adjustments will develop more stress since the development of negative feelings and health problems themselves produce stress.

A. Stimulus Factors - The stimulus factors considered important in the model are divided into two general categories: noise and vibration.

(1) Noise

1. Level
2. Spectral characteristics
  - a. General shape
  - b. Discrete frequency content
3. Temporal characteristics

- a. Time of occurrence
  - b. Duration
  - c. Impulsiveness
  - d. Dwell (temporal concentration)
4. Other characteristics
- a. Rate of change of above
  - b. Directionality and movement

(2) Vibration

- 1. Level
- 2. Spectral content
- 3. Onset/offset characteristics
- 4. Correlation with the aircraft noise
- 5. Generation of secondary sounds (rattles, buzzes, etc.)

B. Situational Factors - The situational factors include the following: activity engaged in, setting, temporal factors, and other environmental conditions.

(1) Activity engaged in

The various activities which may be interrupted by aircraft noise are:

- 1. Relaxation (reverie)
- 2. Aural communications, whether active or passive, with or without visual cues
- 3. Sleep
- 4. Higher order cognitive functioning such as concentration, learning, problem solving, or reading
- 5. Physical activities

(2) Setting

The settings at times of noise exposure which may influence individual reaction are as follows:

1. At home or away
2. With others or alone
3. Indoors or out

(3) Temporal factors

The temporal factors which must be taken into consideration are:

1. Season
2. Day of week
3. Time of day

(4) Other environmental conditions

Other environmental factors which might effect stimulus conditions are as follows:

1. Presence and characteristics of nonaircraft sounds
2. Climatological conditions
  - a. Temperature
  - b. Relative humidity
  - c. Atmospheric pressure
  - d. Wind
  - e. Precipitation
3. Illumination
4. Esthetics of surroundings, auditory, visual, tactile, and olfactory

C. Human factors - The human factors which may be influential in determining one's response to aircraft noise are divided into three general categories as follows: psychological factors, biological-physiological factors, and demographic factors.

(1) Psychological factors

There are at least seven psychological factors to be considered:

1. Attitudes
2. Intelligence
3. Traits
4. Needs
5. Self-concept
6. Values
7. State

(2) Biological-physiological factors

Important biological-physiological factors are:

1. Auditory sensitivity
2. Kinesthetic sensitivity
3. Condition: rested versus fatigued
4. General health
- 5/ State: relaxed versus tense

(3) Demographic factors

Possibly important demographic factors are:

1. Age
2. Sex
3. Occupation
4. Income
5. Education
6. Race
7. Class
8. Owner/Renter

9. Length of residence
10. Previous noise exposure
11. Dependence on aviation

D. Meaning associated with the noise - Kerrick, et al. (ref. A1) found that while noises from a variety of sources were rated equally on the basis of loudness or noisiness, they were not equally acceptable. Gunn, et al. (unpublished results of a study conducted by Langley Research Center personnel at NASA Wallops Station, Virginia) found that aircraft perceived as flying over an individual were rated as more annoying than aircraft perceived as flying off to the side, even at the same PNL. Connor and Patterson (ref. A2) found that "fear" of aircraft crashes was an important determinant of annoyance with aircraft noises. Wilson (ref. A3) found that aircraft noises were more acceptable and less noisy than motor vehicles at the same level. This suggests that the meaning associated with the source of the sound may have an important bearing on the degree of annoyance we feel about various sounds.

E. Activity interruption - In addition to the way we may feel about exposure to unpleasant sounds or the aversive meaning we attach to them, annoyance may result if the noise interferes with an ongoing activity, such as TV viewing, radio listening, sleeping, or activities requiring concentration. The extent of activity interruption could be assessed by questions on a social survey or through prediction based on controlled laboratory tests. There is good reason to think that interruption of these activities may contribute heavily to one's overall annoyance with aircraft noise.

F. Unpleasant characteristics of aircraft noise, per se - The range of possible feelings about the characteristics of a sound, per se, run the gamut

from very pleasant, such as enjoyable music, to very unpleasant, such as a circular saw cutting sheetmetal. Similarly, certain aircraft sounds, at some levels, may actually be pleasant to hear, while other sounds may be perceived as neutral or unpleasant. Molino (ref. A4) developed what he calls "an equal aversiveness curve" for various bands of sound. The shape of the curve most closely resembled that of the inverse of the standard A-weighting characteristic. It is suggested that sounds above the threshold of aversiveness are "punishing" to the ear. Since the Molino data confounds aversiveness of the sound, per se, and interruption of concentration (the subjects were learning Russian during the experiment), the contour might be different under the condition of reverie. Clearly, there is a need to determine the psychophysical relationship between noise parameters and pleasantness or unpleasantness for various sounds. If a sound is perceived as being unpleasant to the ear, then continued exposure may lead to the development of stress in the unwilling listener.

G. Reported feelings - Airport community residents are often polled in order to determine how they feel about aircraft noise, airport operations, the people who are responsible, or the aircraft industry in general. The most commonly asked questions have to do with reported annoyance with aircraft noise. Sometimes people are asked for their overall annoyance, while in other cases they are asked about the annoyance they feel about the interruption of specific activities. In the latter case, the annoyance ratings for the interruption of various activities are usually combined in some way to form a single scale of annoyance. Although such a scale is typically well correlated with the single-question self-rating of annoyance (McKennell, ref. A5), it obviously represents only one particular dimension of annoyance and thus might best be termed "annoyance through disturbance of activities."

Questions are sometimes asked about feelings of "misfeasance" (feelings that those in authority are not doing all they could do to alleviate problems). Feelings of "fear of aircraft crashes" are also probed. The scales used to assess the various feelings are many and varied. Validity of the scales is, for the most part, assumed.

H. Health problems - While the evidence is scanty and sometimes in conflict, certain health-related problems resulting from aircraft noise may be:

1. Permanent hearing loss
2. Gastro-intestinal disorders
3. Increased nervousness
4. Cardio-vascular problems
5. Loss of sleep

Hospital and doctor's records might be helpful in assessing these aircraft noise related health effects.

I. Overt behavior - Few substantive studies have been conducted regarding the overt reaction of people to aircraft noise. Some important forms of overt behavior might be:

1. Moving family out of the noisy area
2. Complaints to authorities
3. Decrease in outdoor activities
4. Decrease in activities involving aural communications
5. Increased time spent out of neighborhood
6. Organizing to reduce the noise

J. Internal adjustment - The increased stress and the development of negative feelings and health problems represent an imbalance of the individual's normal or preferred state. In an effort to return to the normal state



(homeostasis), the individual either takes overt action or makes internal adjustments, both of which serve to reduce the stress. Four types of internal adjustment are identified:

1. Adaptation
2. Habituation
3. Rationalization
4. Resignation

Thus, the individual may adapt to the noise or become habituated to it. Or, the individual may also rationalize his experience and convince himself that his situation is not so bad after all and that others are much worse off than himself.

K. Feedback loops - Every action or nonaction of the individual has a consequence. If the individual cannot or will not take overt action to reduce the stress, or if he does not make internal adjustments, then the development of negative feelings and health problems will themselves increase the stress. These relationships are shown in figure A1 by dashed lines from negative feelings and health problems back to stress. They represent positive feedback loops.

However, if the individual does take some overt action or makes an internal adjustment, then the stress will be relieved through an indirect process. Taking direct action has implications for both the stimulus and the situational factors. For example, through lobbying efforts, the individual may persuade the noise maker to reduce the noise or to change its characteristics so as to make it more tolerable. Or, the individual may change the situation by insulating his home, by spending less time outdoors (thereby decreasing his outdoor exposure time), or by moving out of the noise impacted area. If the individual

makes an internal adjustment, this has implications for the human factors context. For example, the individual, in response to stress, may develop qualities of an "imperturbable" person. Such a person would deny that the noise ever bothered him and, in fact, might report difficulty in even perceiving the noise. These consequences of overt behavior and internal adjustment are represented by dashed lines back to the stimulus and situational factors for the former and back to human factors for the latter. Both are negative feedback loops.

L. The nature of the "filter" variables - As shown in the model diagram, there are no feedback loops to the boxes representing "meaning," "activity interruption," and "unpleasant characteristics." This means only that later elements within the model are not thought to affect these elements. Certainly, events outside the model have an effect. For example, if an aircraft crashes in the near vicinity, the individual may very well associate the next flyover event with a feeling of fear of crash. In a like manner, outside events are thought to produce a certain condition within the individual which tends to "color" his perception of aircraft noise. At any one point in time, these conditions work to predispose individuals to react in certain ways. Over time, however, the conditions can change and the individual's predispositions take on a dynamic character.

M. Hypotheses - A number of specific hypotheses are suggested by the stress reduction model. These are as follows:

1. Increased stimulus from aircraft operations will result in:
  - a. increased development of negative feelings about the noise and/or
  - b. increased development of health problems.

These results will be obtained provided the following elements are held constant:

- (1) Situational factors
  - (2) Human factors
  - (3) Meaning associated with the noise
  - (4) Activity interruption
  - (5) Unpleasant characteristics of the noise, per se
2. The greater the development of negative feelings about the noise
- a. the greater the amount of overt behavior directed toward reducing or eliminating the noise, and/or
  - b. the greater the internal adjustment of the individual.

The model thus suggests that once the situational and human factors are "controlled," and once the individual's perceptions are "filtered," then the following typical outcomes would be expected:

- (1) A reduction in outdoor activities
- (2) An exodus of noise sensitive individuals from the noise impacted area (provided there is an opportunity to move)
- (3) An increase in overt behavior to reduce the noise exposure, e.g., soundproofing
- (4) An increase in health problems
- (5) A rise in atypical living habits, e.g., less conversation
- (6) An increase in positive attitudes toward the noise source for those who make an internal adjustment
- (7) An increase in indicators of other types of stress, e.g., family arguments

## REFERENCES

- A1. Kerrick, J. S.; Nagel, D. C.; and Bennett, R. L.: Multiple Ratings of Sound Stimuli. J. Acoust. Soc. Am., Vol. 45, 1969, pp. 1014-1017.
- A2. Connor, William K.; and Patterson, Harrold P.: Community Reaction to Aircraft Noise Around Smaller City Airports. NASA CR-2104, 1972.
- A3. Wilson, A. H.: Noise. Her Majesty's Stationery Office, London, 1963.
- A4. Molino, John A.: Equal Aversion Levels for Pure Tones and 1/3-Octave Bands of Noise. J. Acoust. Soc. Am., Vol. 55, 1974, pp. 1285-1289.
- A5. McKennell, A. C.: Methodological Problems in a Survey of Aircraft Noise Annoyance. The Statistician 19:(1), 1968.

GUNN/PATTERSON STRESS-REDUCTION MODEL  
OF INDIVIDUAL REACTION TO AIRCRAFT NOISE

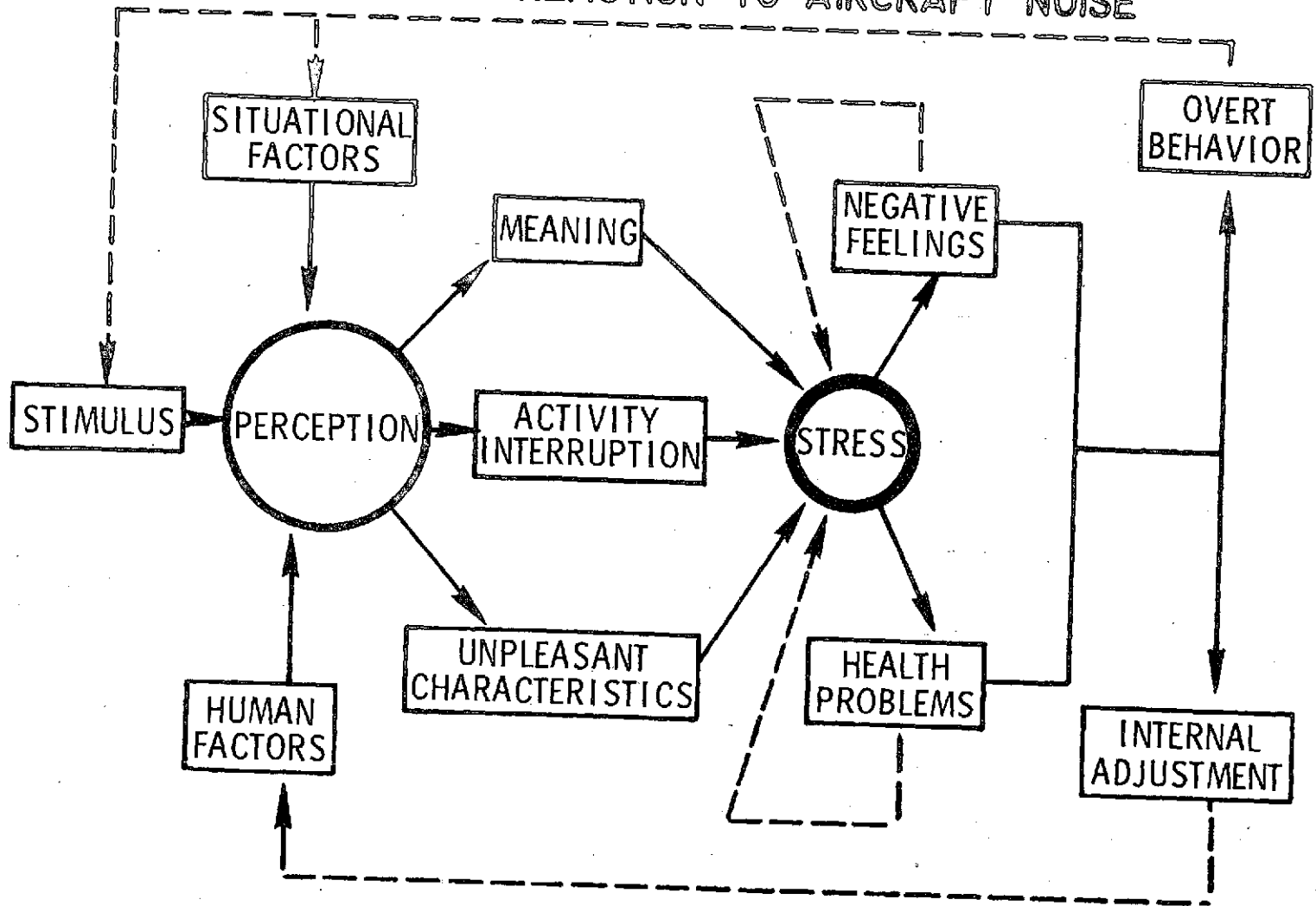


Figure A1.- Gunn/Patterson stress reduction model of individual reaction to aircraft noise.

## APPENDIX B

### INSTRUCTION A

"We would like you to help us in this experiment which has to do with how you feel about the airplane sounds you will hear during the next 30 minutes. During the experiment, you are not to talk to each other. You will be asked for your reaction to the airplane sounds at the end of the session, which, as I said, will last about 1/2-hour."

APPENDIX C

INSTRUCTION B

"We will need to set the listening level of the TV so that it is acceptable to your group. Let's try to find a level which is a good compromise and generally comfortable for all of you."

EXPERIMENTER - FIND ACCEPTABLE LEVEL BY CONSENSUS (IN QUIET).

THEN TURN OFF TV

"Do not readjust the level during the program, please. It is imperative for the purpose of the study that the sound level stay where it is presently set."

## APPENDIX D

### INSTRUCTIONS TO SUBJECTS IN LISTENING PHASE OF THE EXPERIMENT

#### Instructions to Subjects in Telephone Listening Phase of the Experiment

"You are about to take a listening test in which you will be identifying words spoken over the telephone. The two best scoring subjects on the test will receive \$7 each. The four lower scoring subjects will receive \$4 each. If you will pick up your telephone, you will receive more detailed instructions. Remember, during the test, do not cover your open ear and do not switch the phone to the other ear. Listen for the item number that accompanies each word. Some words may be completely masked out in the background noise. Make sure you are checking off a word in the correct box."

#### Recorded Instructions

"Your attention, please.

You are going to hear some one syllable words presented along with different loudness levels of background noise, each word will be presented in a carrier phase giving its particular item number. For example, you will hear phrases like the following:

NUMBER ONE IS TREE  
NUMBER 46 IS MILE

The word presented will be one of the six words printed in a block on your answer sheet for that particular item number. Your task is to identify the word by drawing a line through it on your answer sheet. Look now at the answer sheet marked practice.

Here are some practice words:

NUMBER THREE IS TOW

Within block no. 3 is the correct word tow.

If this is the word you thought you heard, you will have drawn a line through "tow" on the practice answer sheet.

Here is another word.

NUMBER 14 IS BAT

In this case, the correct word was "bat." If this is the word you thought you heard, you will have drawn a line through "bat" within block 14 on the practice answer sheet. In the following exercise, some words will be easier to hear than others.

If you are not sure what the word is--guess. Always draw a line through one of the six words for each item number. If there are any questions, please ask the person in charge now. (Pause)



Please turn now to the answer sheet marked number one and prepare to begin. Remember, always draw a line through a word even if you must guess. After drawing a line through a word, move down to the next numbered block and prepare for the next word. After completing each of the 50 items, turn to the next answer sheet and continue, starting again with item no. 1.

A total of 300 words will be given at the rate of approximately one word every 6 second. The exercise will begin in about 30 seconds."

APPENDIX E

WORD LISTS

- |    |  |    |   |    |  |    |   |
|----|--|----|---|----|--|----|---|
| 1  | lick <u>pick</u> <u>tick</u><br>wick sick kick | 14 | sad sass <u>sag</u><br>sat sap sack       | 27 | sung sup sun<br>sud <u>sum</u> sub               | 40 | cave canc came<br>cape <u>cake</u> case   |
| 2  | seat <u>meat</u> beat<br>heat neat feat        | 15 | sip <u>sing</u> sick<br>sin sill sit      | 28 | red wed shed<br>bed <u>led</u> fed               | 41 | game tame <u>name</u><br>fame same came   |
| 3  | pus pup pun<br>puff puck <u>pub</u>            | 16 | sold told hold<br>cold <u>gold</u> fold   | 29 | hot got <u>not</u><br>tot lot pot                | 42 | oil foil toil<br>boil <u>soil</u> coil    |
| 4  | <u>look</u> hook cook<br>book took shook       | 17 | buck but bun<br>bus buff <u>bug</u>       | 30 | dud dub dun<br><u>dug</u> dung duck              | 43 | fin fit <u>fig</u><br>fizz fill fib       |
| 5  | tip lip <u>rip</u><br>dip sip <u>hip</u>       | 18 | <u>lake</u> lace lame<br>lane lay late    | 31 | pip pit pick<br>pig pill <u>pin</u>              | 44 | cut cub cuff<br>cuss <u>cud</u> cup       |
| 6  | rate rave raze<br>race <u>ray</u> rake         | 19 | gun run <u>nun</u><br>fun sun bun         | 32 | seem seethe <u>seep</u><br>seen seed <u>seek</u> | 45 | <u>feel</u> eel reel<br>heel peel keel    |
| 7  | bang rang sang<br>gang <u>hang</u> fang        | 20 | <u>rust</u> dust just<br>must bust gust   | 33 | day <u>say</u> way<br>may <u>gay</u> pay         | 46 | <u>dark</u> lark bark<br>park mark hark   |
| 8  | <u>hill</u> till bill<br>fill kill will        | 21 | <u>pan</u> path pad<br>pass pat pack      | 34 | rest best test<br><u>nest</u> vest west          | 47 | heap heat heave<br>hear <u>heath</u> heal |
| 9  | mat man mad<br>mass <u>math</u> map            | 22 | dim dig dill<br>did din <u>dip</u>        | 35 | pane pay pave<br>pale pace <u>page</u>           | 48 | men then hen<br>ten pen <u>den</u>        |
| 10 | tale pale <u>male</u><br>bale gale sale        | 23 | wit fit kit<br>bit <u>sit</u> hit         | 36 | bat bad back<br>bath ban <u>bass</u>             | 49 | raw paw law<br>saw <u>thaw</u> jaw        |
| 11 | sake sale save<br><u>same</u> safe sane        | 24 | din tin <u>pin</u><br>sin win <u>fin</u>  | 37 | cop top <u>mop</u><br>pop shop hop               | 50 | bead beat bean<br>beach <u>beam</u> beak  |
| 12 | peat peak peace<br>peas <u>peal</u> peach      | 25 | teal teach team<br>tease <u>teak</u> tear | 38 | fig pig rig<br>dig wig <u>big</u>                |    |   |
| 13 | king kit <u>kill</u><br>kin kid kick           | 26 | tent bent <u>went</u><br>sent rent dent   | 39 | <u>tap</u> tack tang<br>tab tan tam              |    |   |

1	went sent bent dent tent rent	14	not tot <u>got</u> pot hot lot	27	<u>peel</u> reel feel eel keel heel	40	mass math map <u>mat</u> man mad
2	hold cold told fold <u>sold</u> gold	15	vest <u>test</u> rest best west nest	28	hark <u>dark</u> mark bark park lark	41	ray raze <u>rate</u> rave rake race
3	pat pad pan path <u>pack</u> pass	16	pig pill pin pip <u>pit</u> pick	29	heave hear <u>heat</u> heal heap heath	42	save same sale sane <u>sake</u> safe
4	lane lay late <u>lake</u> lace lame	17	back bath <u>bad</u> bass bat ban	30	cup <u>cut</u> cud cuff cuss cub	43	fill kill will <u>hill</u> till bill
5	kit bit fit hit wit <u>sit</u>	18	way may say pay <u>day</u> gay	31	<u>thaw</u> law raw paw jaw saw	44	sill sick sip sing <u>sit</u> sin
6	must bust gust rust dust <u>just</u>	19	pig big <u>dig</u> wig rig fig	32	pen hen men then den <u>ten</u>	45	bale <u>gale</u> sale tale pale male
7	<u>teak</u> team teal teach tear tease	20	pale <u>pace</u> page pane pay pave	33	puff puck pub <u>pus</u> pup pun	46	wick sick kick <u>lick</u> pick tick
8	<u>din</u> dill dim dig dip did	21	<u>cane</u> case cape cake came cave	34	bean beach beat beak bead <u>beam</u>	47	<u>peace</u> peas peak peach peat peal
9	bed led fed red <u>wed</u> shed	22	shop mop <u>cop</u> top hop pop	35	heat neat feat seat <u>meat</u> beat	48	<u>bun</u> bus but bug buck buff
10	pin sin <u>tin</u> fin din win	23	<u>coil</u> oil soil toil boil foil	36	dip sip <u>hip</u> tip lip rip	49	<u>sag</u> sat sass sack sad sap
11	dug dung duck <u>dud</u> dub dun	24	tan tang tap <u>tack</u> tam tab	37	kill <u>kin</u> kit kick king kid	50	fun sun bun gun <u>run</u> nun
12	<u>sum</u> sun sung sup sub sud	25	fit fib <u>fizz</u> fill fig fin	38	<u>hang</u> sang bang rang fang gang		
13	<u>seep</u> seen see the seek seem seed	26	same name game <u>tame</u> came fame	39	took cook look <u>hook</u> shook book		

1	gold hold <u>sold</u> told fold cold	14	heal heap heath <u>heave</u> hear heat	27	bus buff bug buck but <u>bun</u>	40	soil toil <u>oil</u> foil coil <u>boil</u>
2	lame lane lace late <u>lake</u> lay	15	paw jaw saw thaw law raw	28	tick wick pick kick <u>lick</u> sick	41	came <u>cape</u> cane case cave cake
3	bust just rust dust <u>gust</u> must	16	pub <u>pus</u> puck pun <u>puff</u> pup	29	sin sill sit sip sing <u>sick</u>	42	wig rig <u>fig</u> pig big <u>dig</u>
4	did din dip dim dig <u>dill</u>	17	meat. feat heat neat beat <u>seat</u>	30	name fame tame came <u>game</u> same	43	ban back bat <u>bad</u> bass bath
5	sin <u>win</u> fin din tin pin	18	<u>kit</u> kick kin kid kill king	31	safe save sake sale sane <u>same</u>	44	test nest best west <u>rest</u> vest
6	sun sud sup <u>sub</u> sung sum	19	cook book hook shook <u>look</u> took	32	map <u>mat</u> math mad <u>mass</u> man	45	seen seed seek seem seethe <u>seep</u>
7	lot not hot got <u>pot</u> tot	20	race ray rake rate rave raze	33	gang hang fang bang rang <u>sang</u>	46	<u>dun</u> dug dub duck dud dung
8	pill pick pip pit <u>pin</u> pig	21	bill fill <u>till</u> will hill kill	34	sip rip tip lip hip <u>dip</u>	47	led shed red wed fed <u>bed</u>
9	may <u>gay</u> pay day say way	22	sap sag <u>sad</u> sass sack sat	35	beach beam beak bead beat bean	48	tease teak <u>tear</u> teal teach team
10	pave <u>pale</u> pay page pane pace	23	gale <u>male</u> tale pale sale bale	36	<u>hen</u> ten then den men pen	49	bit sit hit wit <u>fit</u> kit
11	pop shop <u>hop</u> cop top mop	24	<u>peas</u> peal peach peat peak peace	37	<u>cuff</u> cuss cub cup cut cud	50	pad pass <u>path</u> pack pan pat
12	tang tab tack tam <u>tap</u> tan	25	rent went tent bent dent <u>sent</u>	38	park mark hark dark <u>lark</u> bark		
13	keel feel peel <u>reel</u> heel sel	26	sun nun gun run bun <u>fun</u>	39	fizz <u>fill</u> fib fin fit fig		

1 kick lick sick  
tick wick pick

2 neat beat seat  
meat feat heat

3 pun puff pup  
pub pus puck

4 hook shook book  
took cook look

5 lip hip dip  
sip rip tip

6 rake rate ray  
raze race rave

7 fang bang hang  
sang gang rang

8 will hill kill  
bill fill till

9 map mat math  
mad mass man

10 pale sale bale  
gale male tale

11 sane sake safe  
save same sale

12 peak peach peas  
peal peace peat

13 kin kid kick  
king kit kill

14 sack sad sap  
sag sat sass

15 sit sip sill  
sick sin sing

16 fold sold gold  
hold cold told

17 but bug bus  
buff bun buck

18 late lake lay  
lame lane lace

19 run bun fun  
sun nun gun

20 dust gust must  
bust just rust

21 path pack pass  
pat pad pan

22 dip dim din  
dill did dig

23 fit hit bit  
sit kit wit

24 tin fin sin  
win pin din

25 tear teal teak  
team tease teach

26 dent tent rent  
went sent bent

27 sup sub sud  
sum sun sung

28 wed fed bed  
led shed red

29 pot hot lot  
not tot got

30 duck dud dung  
dun dug dub

31 pit pin pig  
pill pick pip

32 seethe seek seen  
seed seep seem

33 say pay may  
gay way day

34 best rest nest  
vest test rest

35 page pane pace  
pave pale pay

36 bass bat ban  
back bath bad

37 hop cop shop  
mop pop top

38 dig wig big  
fig pig rig

39 tack tam tab  
tan tang tap

40 cake came cave  
cane case cape

41 tame came fame  
same name game

42 toil boil foil  
coil oil soil

43 fig fizz fit  
fib fin fill

44 cuss cud cup  
cut cub cuff

45 heel peel keel  
feel eel reel

46 mark bark dark  
lark hark park

47 heath heave heap  
heat heal hear

48 then den ten  
pen hen men

49 law saw paw  
jaw raw thaw

50 beat beak beach  
beam bean bead

1 sent rent dent  
tent hent went

2 told fold cold  
gold hold sold

3 pass pat pack  
pan path pad

4 lay lame lake  
lace late lane

5 sit kit wit  
fit hit bit

6 just must dust  
gust rust bust

7 team tease teach  
tear teal teak

8 dill did dig  
dip dim din

9 shed bed wed  
fed red led

10 win pin din  
tin fin sin

11 dung dun dud  
dub duck dug

12 sud sum sub  
sung sup sun

13 seed seep seem  
seethe seek seen

14 tot lot pot  
not got not

15 nest vest west  
rest best test

16 pick pig pit  
pin pip pill

17 bath ban bass  
bat bad back

18 gay way day  
say pay may

19 rig dig pig  
big fig wig

20 pace pave pane  
pay page pale

21 cape cake case  
cave cane came

22 mop pop top  
hop cop shop

23 boil soil coil  
oil foil toil

24 tab tan tam  
tap tack tang

25 fill fig fin  
fit fib fizz

26 fame same came  
game tame name

27 reel heel eel  
keel feel peel

28 bark park lark  
hark dark mark

29 hear heath heal  
heap heat heave

30 cud cuff cut  
cub cup cuss

31 saw thaw jaw  
raw paw law

32 den men pen  
hen ten then

33 puck pun pus  
pup pub puff

34 beak bead beam  
bean beach beat

35 beat heat meat  
feat seat neat

36 hip tip sip  
rip dip lip

37 kid kill king  
kit kick kin

38 rang fang gang  
hang sang bang

39 shook look took  
cook book hook

40 man map mass  
math mad mat

41 rave rake race  
ray raze rate

42 sale sane same  
safe save sake

43 till will fill  
kill bill hill

44 sick sin sing  
sit sip sill

45 sale tale gale  
male bale pale

46 sick tick lick  
pick kick wick

47 peach peat peal  
peace peas peak

48 buff bun buck  
but bug bus

49 sass sack sat  
sap sag sad

50 nun fun run  
bun gun sun

1 cold gold fold  
sold told hold

2 lace late lane  
lay lame lake

3 gust rust bust  
just must dust

4 dig dip did  
din dill dim

5 fin din win  
pin sin tin

6 sub sung sum  
sun sud sup

7 got pot tot  
lot not hot

8 pin pip pill  
pick pig pit

9 pay day gay  
way may say

10 pay page pale  
pace pave pane

11 top hop pop  
shop mop cop

12 tam tap tan  
tang tab tack

13 eel keel heel  
peel reel feel

14 heat heal hear  
heath heave heap

15 jaw raw thaw  
law saw paw

16 pup pub puff  
puck pun pus

17 feat seat neat  
beat heat meat

18 kick king kid  
kill kin kit

19 book took shook  
look hook cook

20 raze race rave  
rake rate ray

21 kill bill hill  
till will fill

22 sat sap sack  
sad sass sag

23 male bale pale  
sale tale gale

24 peal peace peat  
peak peach peas

25 bent dent sent  
rent went tent

26 bun gun sun  
nun fun run

27 bug buck buff  
bun bus but

28 pick kick wick  
sick tick lick

29 sing sit sin  
sill sick sip

30 came game same  
name fame tame

31 sake sale save  
same safe sane

32 math mad mat  
man map mass

33 sang gang rang  
fang bang hang

34 rip dip lip  
hip tip sip

35 beam bean bead  
beat beak beach

36 ten pen den  
men then hen

37 cup cup cuss  
cud cuff cut

38 lark hark park  
mark bark dark

39 fib fin fill  
fig fizz fit

40 foil coil boil  
soil toil oil

41 case cave cake  
came cape cane

42 big fig wig  
rig dig pig

43 bad bass bath  
ban back bat

44 west rest vest  
test nest best

45 seek seem seed  
seep seen seethe

46 dub duck dug  
dung dun dud

47 fed red led  
shed bed wed

48 teach tear tease  
teak team teal

49 hit wit sit  
kit bit fit

50 pack pan pat  
pad pass path



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