NASA Technical Memorandum 80106

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JUNE 1979

(NASA-TM-80106) EFFECT OF HELICOPTER NOISE ON PASSENGER ANNOYANCE (NASA) 18 p HC A02/MF A01 CSCL 01C N79-26782

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G3/71 26032

NASA
National Aeronautics and Space Administration

Langley Research Center
Hampton, Virginia 23665

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ABSTRACT

A laboratory study was conducted to determine the effects of helicopter interior noise on passenger annoyance for both reverie and listening situations as well as the relative effectiveness of several metrics (OASPL, dB(A), SIL) for quantifying annoyance response for these situations. The noise stimuli were based upon recordings of the interior noise of the NASA Civil Helicopter Research Aircraft. These noises were presented at levels ranging from approximately 70 to 86 dB(A) with various tonal components selectively attenuated to give a range of spectra. The listening task required the subjects to listen to and record phonetically-balanced (PB) words presented within the various noise environments. Results indicate that annoyance during a listening condition is generally higher than annoyance under a reverie condition for corresponding interior noise environments. Attenuation of the tonal components results in increases in listening performance but has only a small effect upon annoyance for a given noise level. The noise metric most effective for estimating annoyance response under conditions of reverie and listening situations is shown to be the A-weighted sound pressure level.

INTRODUCTION

The assessment and control of helicopter interior noise is influenced by such factors as hearing damage risk, general passenger annoyance, and activity interference. However, the relatively high levels of noise, the low-frequency content of the noise spectrum, and the presence of tonal components due to transmission gear-clash pose a challenge to noise control and environmental assessment activities. Although studies of the physical noise environment of helicopters (ref. 1, for example) have been reported, relatively few studies have considered interior noise effects upon passenger acceptance. The purpose of this study is to examine the effects of helicopter noise of varying tonal content on overall passenger annoyance under both listening and reverie conditions. In addition, the effect of noise on listening performance as well as the effectiveness of various metrics for quantifying annoyance response are described.

METHOD

Simulator

The simulator used for this study was the Langley Passenger Ride Quality Apparatus (PRQA). The PRQA is described briefly in this section and a detailed description can be obtained from references 2 and 3. The PRQA and associated programing and control instrumentation are shown in figure 1. Included are photographs of the waiting room where subjects are instructed as to their participation in the experiment, questionnaires are completed, etc.; the exterior of PRQA (It should be noted that the actual mechanisms which drive the simulator are located beneath the floor.); a model of the simulator indicating the supports, actuators, and restraints of the three-axis drive system; the control console which is located at the same level as the simulator to allow the console operator to constantly monitor subjects within the simulator; an interior view of PRQA fitted with tourist-class aircraft seats; and additional interior views (with front or back panels removed).

Subjects

A total of 84 subjects (15 males and 69 females) participated in the study. The volunteer subjects were obtained from a contractual subject pool and were paid for their participation in the study. The ages of the subjects ranged from 18 to 60 years, with a median age of 31 years. The mean weight of the subjects was 63 kg (138 lb), with a standard deviation of 11 kg (24 lb). All subjects were audiometrically screened and had normal hearing.

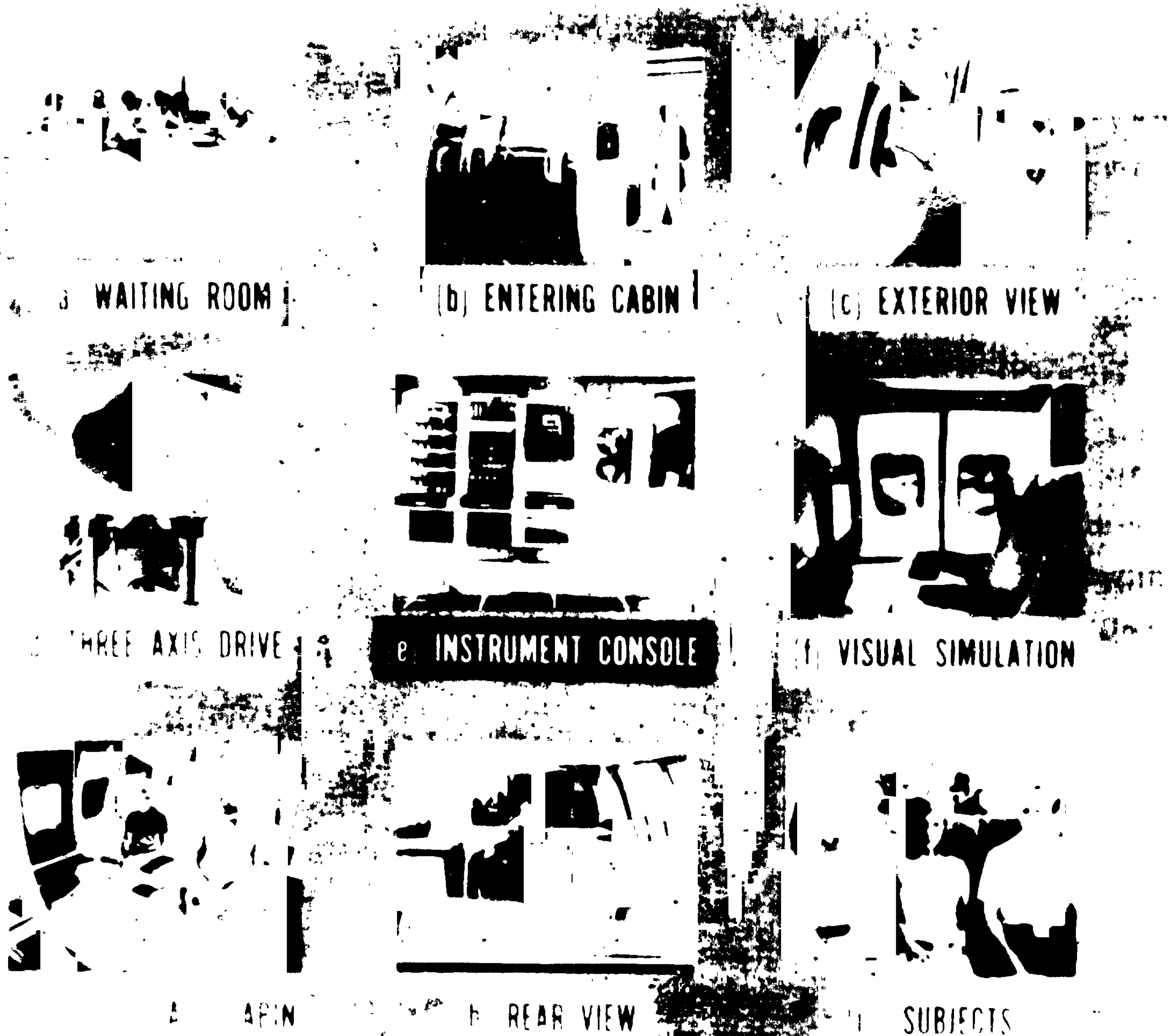


Figure 1.- Passenger ride quality apparatus.

Vibration and Noise Stimuli

The interior noise of the NASA Civil Helicopter Research Aircraft (Sikorsky CH-53A) was prerecorded and played through appropriate filters into the PRQA sound system while the passenger cabin was simultaneously vibrated in the vertical direction with narrow band (bandwidth of 9 Hz, centered at 4.5 Hz) random vibration at a level of 0.02 g_{rms}. The noise levels varied from 86 dB(A) (highest level with no filtering) to 68 dB(A) (lowest level with filtering). Prerecorded speech (PB words) were played into the passenger cabin using a separate sound system. The speech level at the subjects' head locations was approximately 76 dB(A) for all noise exposures and were within ± 1 dB for all subjects.

Procedure

The tasks for each subject (six subjects concurrently) were to (1) provide annoyance ratings of each noise stimulus condition using a nine-point unipolar scale where "0" corresponds to "zero annoyance" and "8" refers to "maximum annoyance, and (2) listen for and record PB words presented along with the interior noise for certain of the noise stimuli. Each noise stimulus condition lasted for 1 minute. At the end of each noise exposure, the subjects rated their annoyance using the scale mentioned above. The rating sheets and the experimental design are shown in figure 2. As indicated, a total of four noise levels and four filter (spectral) conditions were investigated for the listening task and reverie (no task) conditions. The various spectral conditions (SC) are shown in figure 3. The order of noise/word exposures was randomized twice (without replacement), and counterbalanced for presentation to the subjects. Thus, each noise stimulus condition was presented twice to the subjects. A typical day of testing involved exposing each subject group to 32 noise stimuli followed by a 15-minute rest period after which the remaining 32 stimuli were applied.

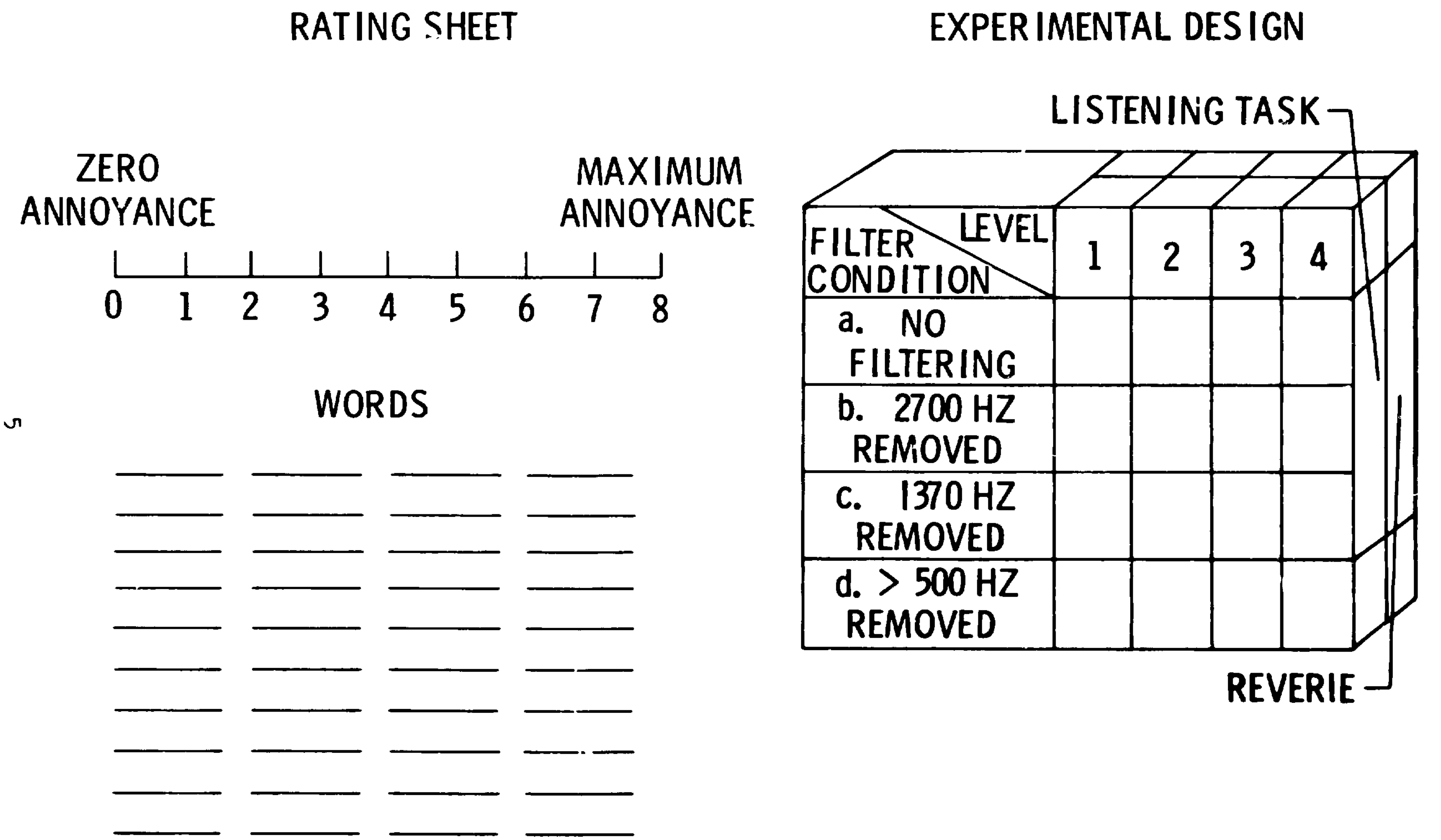
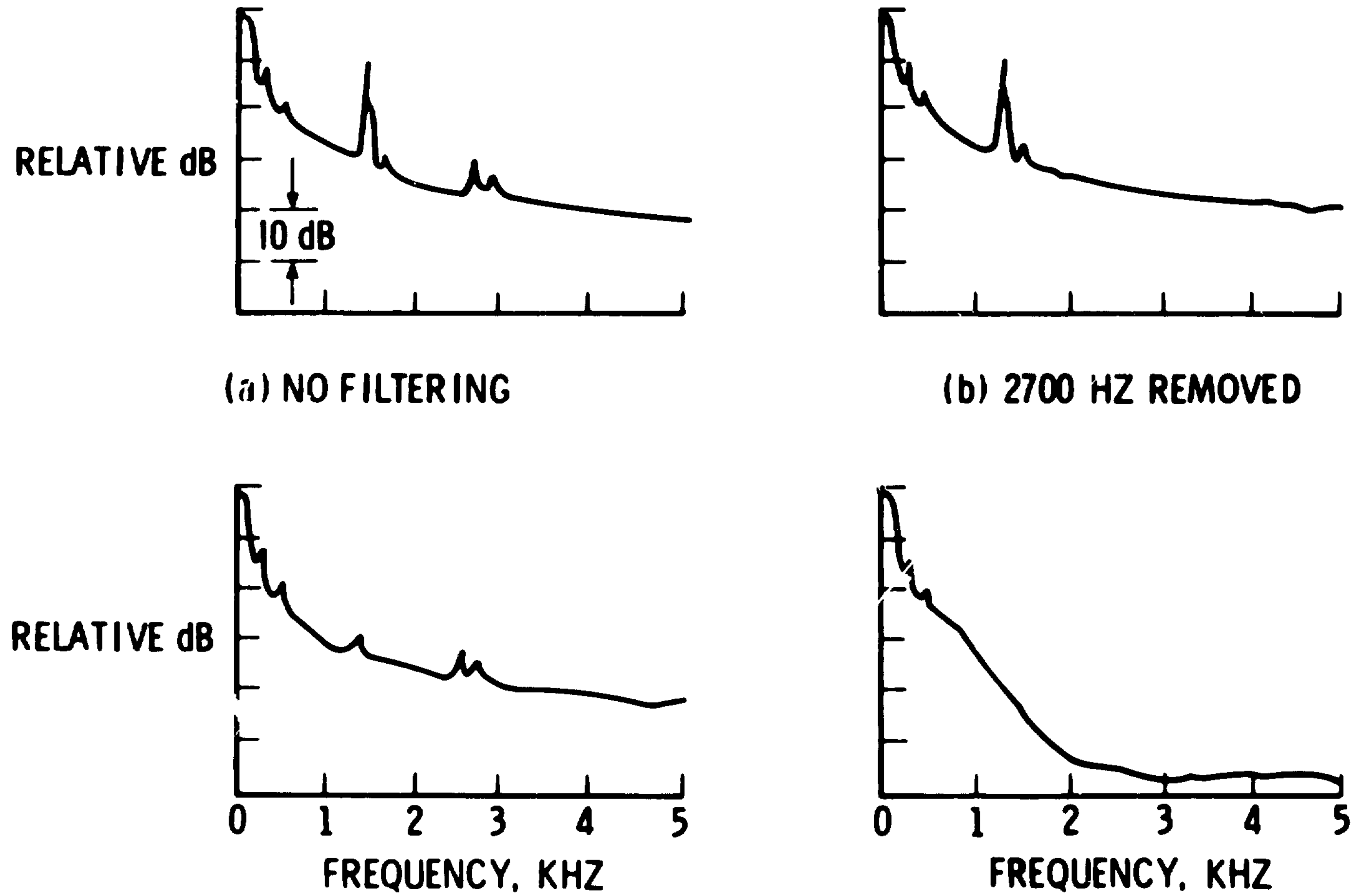


Figure 2.- Rating sheet and experimental design.



(a) NO FILTERING

(b) 2700 HZ REMOVED

(c) 1370 HZ REMOVED

(d) > 500 HZ REMOVED

Figure 3. - Narrow band spectra used in study.

RESULTS AND DISCUSSION

Results are presented in figures 4 through 7. The effect upon listening task performance due to filtering of the tonal components is shown in figure 4. It is seen that the percentage of words correct increases substantially when the gear tonal components are attenuated. Whether the improvement in listening task performance is due to the reduced levels of noise or due to the absence of the tonal components cannot be positively determined from these data. However, the small region of overlap between the two curves (73-76 dB(A)) indicates an improvement in listening task performance of approximately 15 percent for the case where tones are removed. A comparison of annoyance response data for both reverie and listening task conditions and for each of the four spectral conditions is shown in figure 5. It is apparent that the annoyance ratings obtained during the listening task condition were generally higher than those during reverie at all noise levels. This is further illustrated in figure 6 which shows the least square lines fitted to the data of figure 5 as well as a comparison to similar data presented in reference 4. There is good agreement between the results of the two studies with both indicating that a penalty of about 1.8 to 3.1 dB(A) may be appropriate for assessing the influence of the task interruption upon annoyance response within the context of this study.

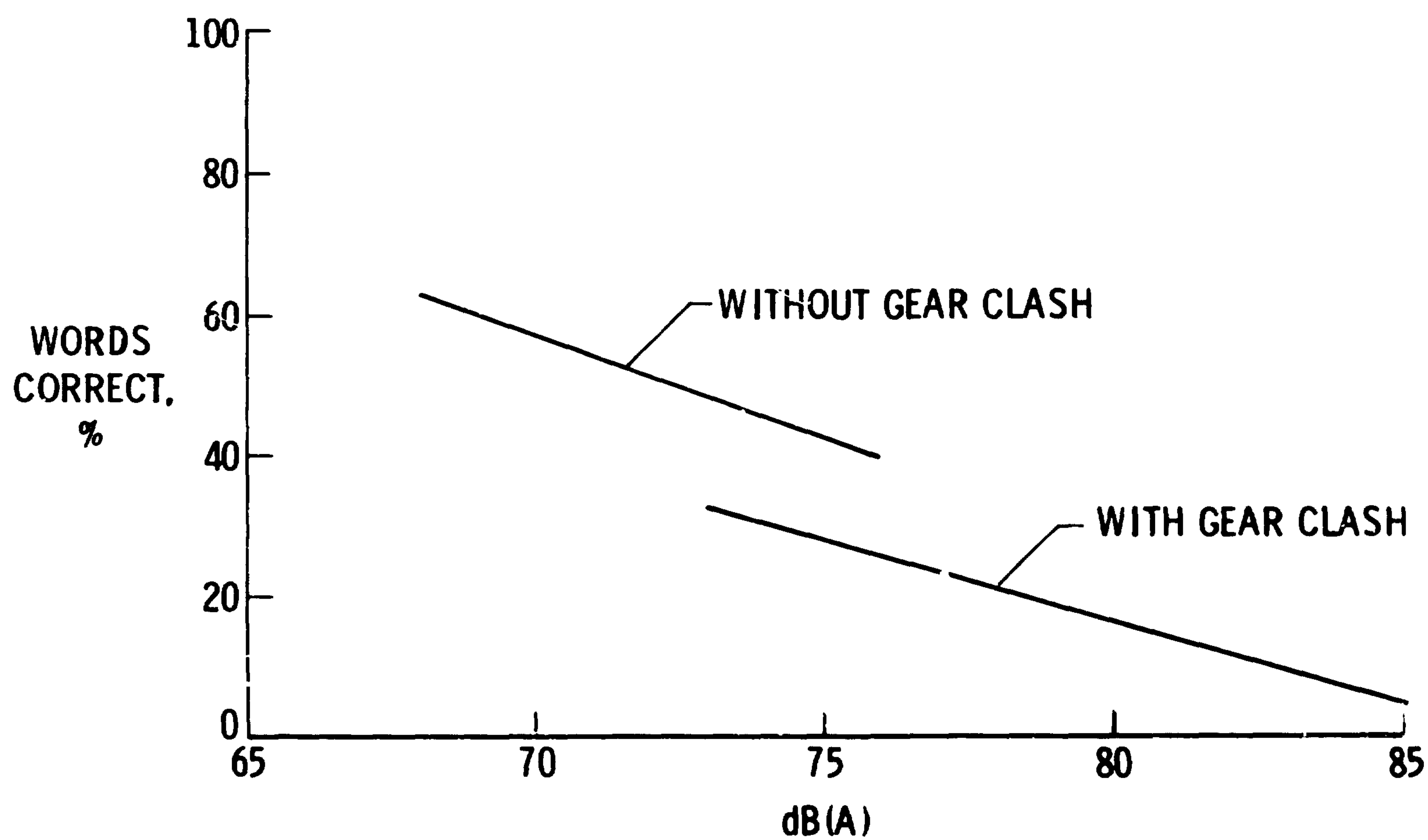


Figure 4. - Results of listening task with and without gear clash component.

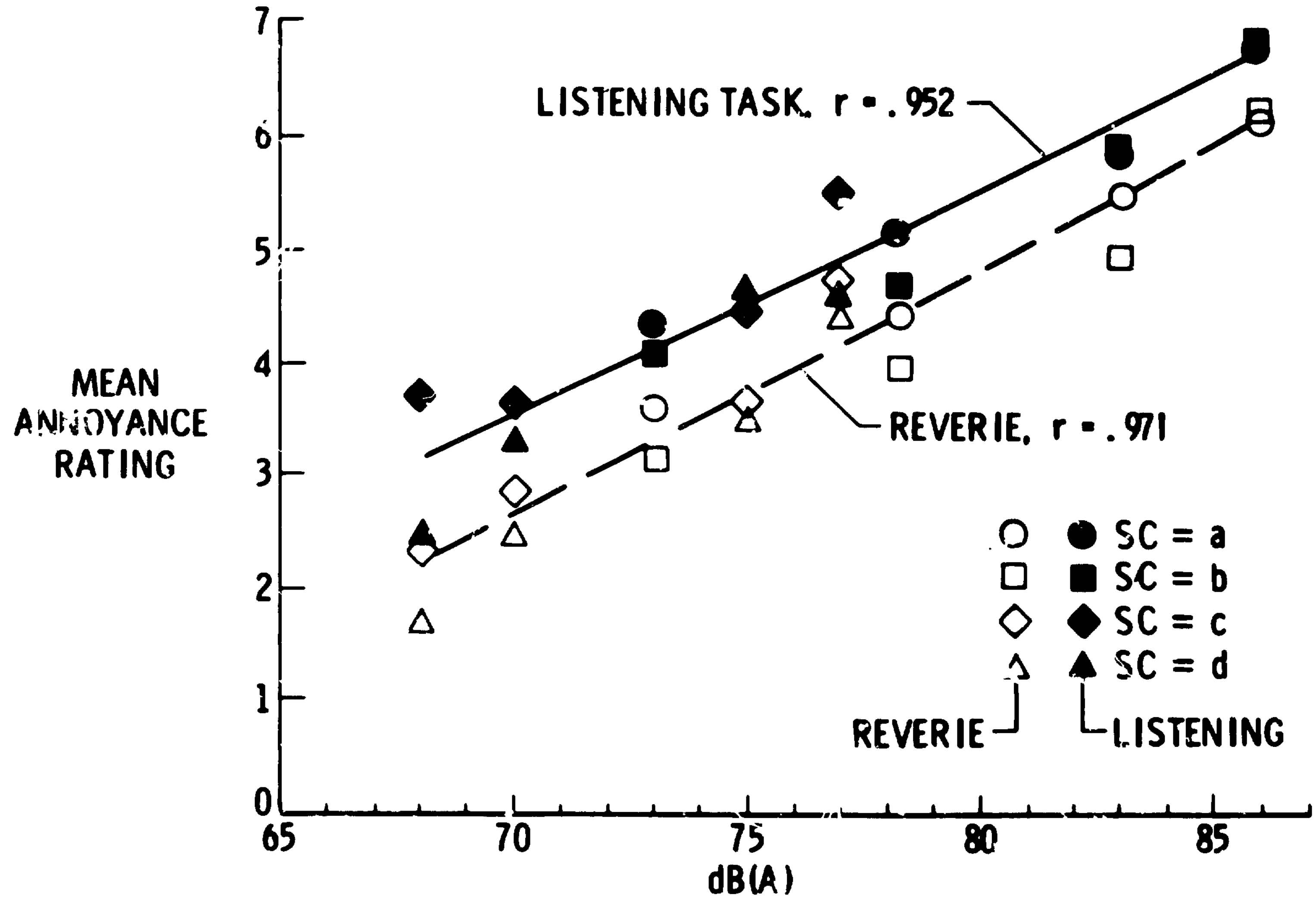


Figure 5. - Comparison of annoyance for various spectral conditions.

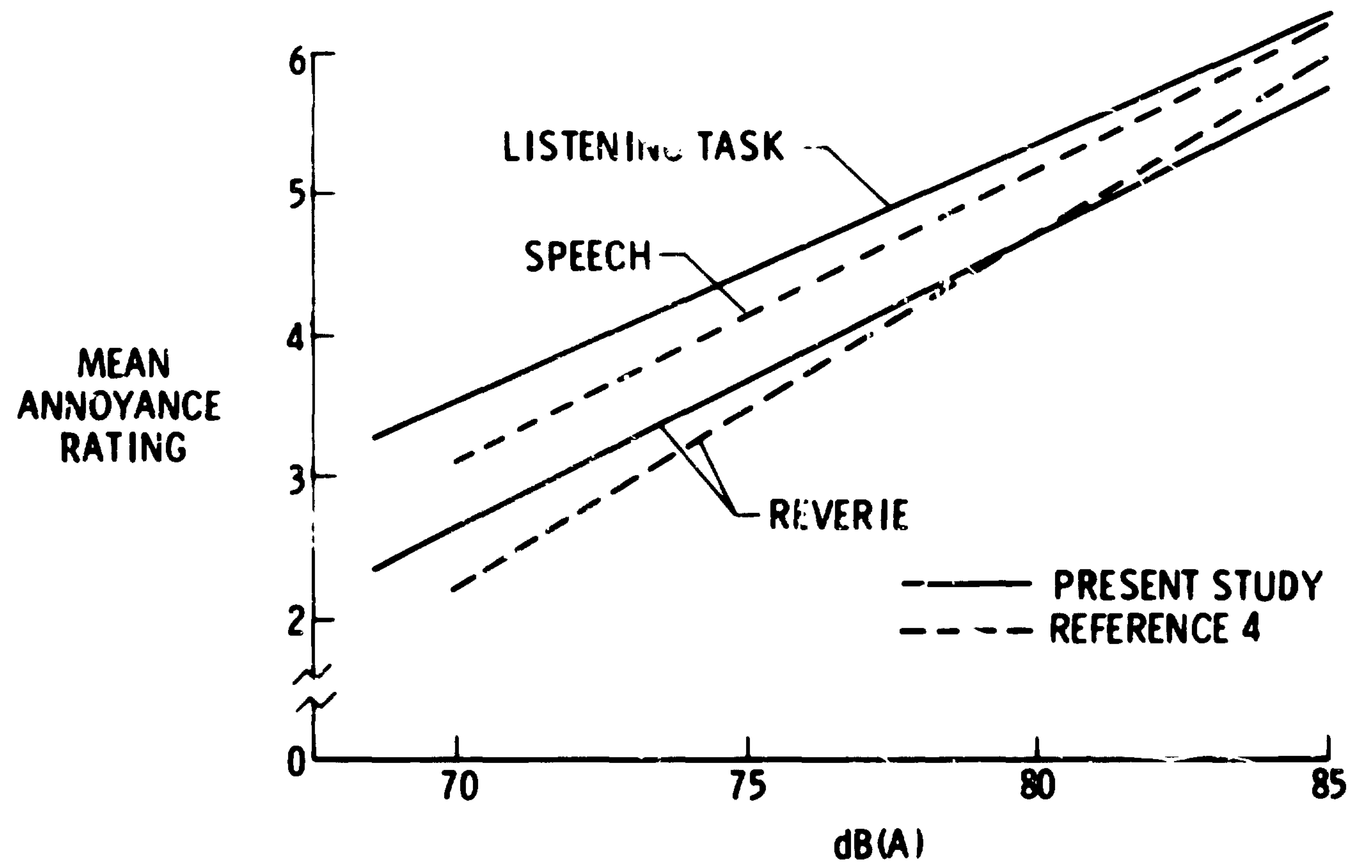


Figure 6.- Comparison of results of present paper with ... 4.

Comparisons of Descriptors

The mean annoyance ratings as a function of noise levels for the three noise descriptors, SIL, dB(A), and OASPL, are shown in figure 7 for the reverie and listening task conditions. Also shown are the respective correlation coefficients between mean annoyance rating and noise level for each descriptor and condition. As indicated, the annoyance responses were always greater for the listening task condition than for the reverie condition. The differences in annoyance level were greatest using the unweighted overall sound pressure level, OASPL, and least using speech interference level, SIL. It is seen that the correlations were highest for the dB(A) metric and generally slightly larger for the reverie condition. Subsequent statistical tests indicated that the dB(A) descriptor correlates better with mean annoyance response than OASPL for both the task and reverie conditions and better than SIL for the reverie condition. This implies that, within the context of the present study, dB(A) was the most appropriate measure for estimating annoyance response within the civil helicopter interior noise environment.

DESCRIPTOR	COR. COEF.	
	TASK	REVERIE
SIL	.917	.933
dB(A)	.952	.971
OASPL	.851	.889

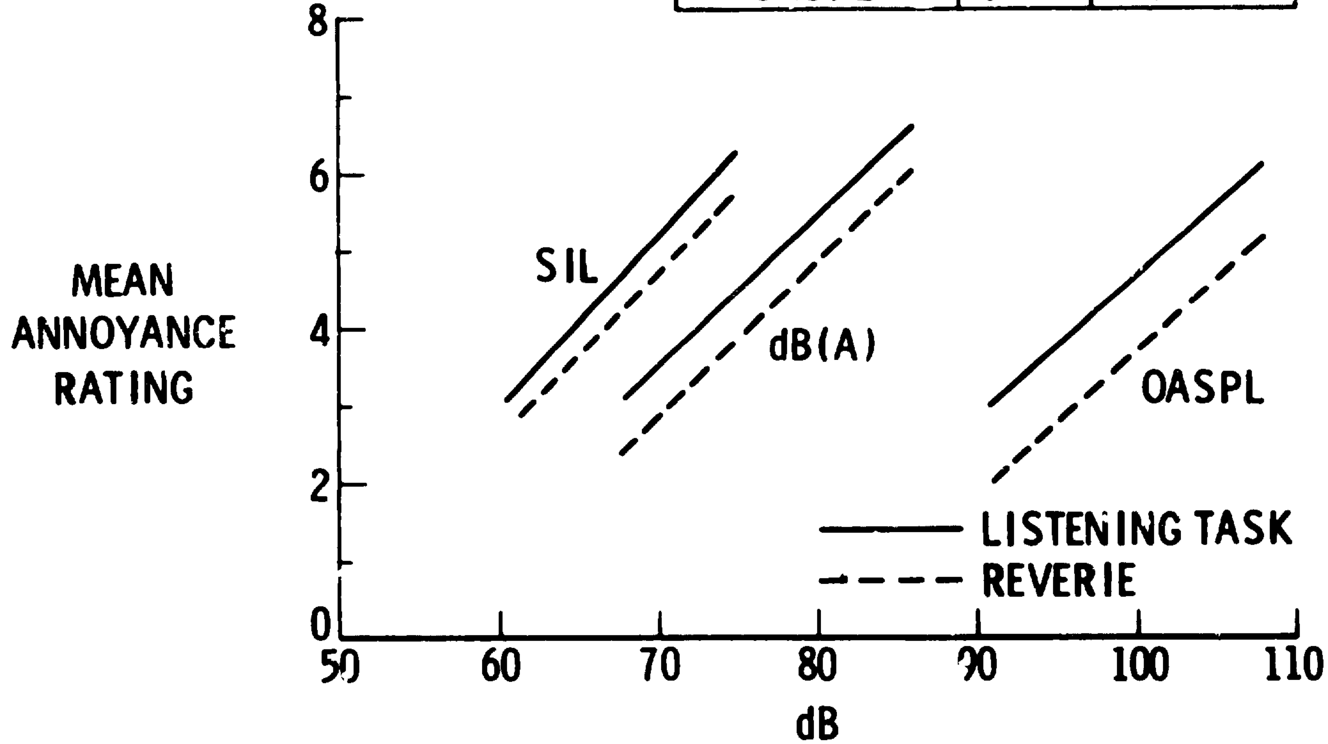


Figure 7.- Comparison of annoyance rating for various descriptors both during reverie and during the listening task.

CONCLUDING REMARKS

Subjective annoyance to helicopter interior noise is greatest when subjects are engaged in a listening task as opposed to a reverie condition.

Listening performance is improved when the gear-clash components of the interior noise spectrum are removed.

The dB(A) descriptor is the most appropriate correlate of annoyance under both reverie and listening task conditions.

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
Technical Memorandum 80106		

4. Title and Subtitle	5. Report Date
EFFECT OF HELICOPTER NOISE ON PASSENGER ANNOYANCE	June 1979
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Sherman A. Clevenson and Jack D. Leatherwood	
	10. Work Unit No.
9. Performing Organization Name and Address	505-09-13-11
NASA Langley Research Center Hampton, Virginia 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

For presentation at the 97th Meeting of the Acoustical Society of America, June 11-15, 1979, Cambridge, Massachusetts.

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17. Key Words (Suggested by Author(s))	18. Distribution Statement
helicopter interior noise, passenger annoyance, reverie and listening situations, ride quality, human response	Unclassified - Unlimited Subject Category 53

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	15	$4.00

* For sale by the National Technical Information Service, Springfield, Virginia 22161