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Comparison of Audiograms Determined Using Pure Tone and One-third Octave Bands of Noise as Stimuli for the Chinchilla

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Audiograms were obtain from chinchillas using conventional pure tone stimuli and using 1/3 octave bands of noise as stimuli. The average hearing threshold levels in dB SPL were found to be comparable. The audiograms determined using the 1/3 octave bands of noise were slightly more reliable (lower test-retest variability).

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Introduction

The chinchilla audiometric procedure currently in use for noise hazard studies at the U.S. Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama, uses pure tone stimuli in a sound field test environment (Patterson et al., 1986). The animals are trained in a shuttlebox to respond to sounds by moving from where they are to the other end of the shuttlebox. They are free to move about the test cage throughout the test. The tonal test stimuli are presented by a speaker located in one corner of an audiometric room with sound absorbing walls, thus creating a progressive and directional sound field. The animals are typically monaural. This leads to a possibility that they may orient their "hearing" ear differently with respect to the sound source from time to time. Since the orientation of the head relative to a sound source affects the level reaching the ear, the threshold will vary as the orientation is changed. This adds to the measurement error and is a source of uncontrolled variability in the threshold shifts measured in noise exposure studies.

An obvious solution to this problem is to always orient the subject's ear toward the sound source. One way to assure that the subject is always orienting the ear of interest toward the sound source is to make the source surround the subject. This can be done by using a quasireverberant test room to produce a nondirectional sound field. The ANSI standard method for real ear attenuation (ANSI, 1984) is based on this type of sound field. It uses one-third octave bands of noise originating from three speakers in a hard walled room as audiometric test stimuli. This study was undertaken to determine whether an audiometric test procedure for the chinchilla based on this quasireverberant sound field will lead to more reliable threshold estimates.

Methods

The subjects for this study were five male chinchillas from the USAARL chinchilla colony. They were monauralized by surgical destruction of the left cochlea. The surgery was done with the animal anesthetized by isoflurane gas inhalation. Aseptic procedures were followed during surgery. At least 1 week recovery was allowed after surgery before audiometric training or testing was conducted.

The audiometric testing employed a shock avoidance procedure in a two compartment shuttlebox (Patterson et al., 1986). The one-third octave band stimuli had center frequencies at 0.125, 0.25, 0.5, 1.0, 1.6, 2.0, 3.15, 4.0, 6.3, and 8.0 kHz. Each subject was trained in the audiometric procedure using one-third octave bands of noise until their thresholds reached asymptote. Then, 20 additional audiograms were obtained using the noise stimuli. This was followed by five audiograms using pure tone stimuli for transition training. Finally, 15 to 20 pure tone audiograms were obtained. The pure tone stimuli had frequencies of 0.125, 0.25, 0.5, 1.0, 1.4, 2.0, 2.8, 4.0, 5.6, and 8.0 kHz.

The 15 to 20 audiograms from each type of test stimulus were used to calculate a test-retest variance estimate for each subject (except for one subject who died before completing the pure tone test) at each test frequency. Under the null hypothesis that there is no difference in the test-retest variability of these two procedures, the ratio of these variance estimates is distributed as F (Brownlee, 1960). This test was used to determine the significance of differences in test-retest reliability of the two procedures.

Results and discussion

Table 1 contains the average audiometric thresholds determined using the one-third octave band stimuli and the standard deviation of these thresholds for each of the five subjects. These

Table 1.
Average values and standard deviations of the thresholds determined using one-third octave bands of noise.

Frequency in kHz

Subject	0.125	0.250	0.50	1.0	1.6	2.0	3.1	4.0	6.3	8.0
X63	21.8	13.0	2.5	2.3	1.3	2.0	-3.5	-1.8	0.8	-1.5
sd	8.8	4.2	4.2	5.8	5.7	5.7	3.7	6.8	7.8	3.7
X64	20.5	10.0	-1.3	-2.8	1.8	-1.3	0.3	-0.3	2.8	-0.3
sd	4.3	6.0	5.0	5.6	5.3	3.1	4.9	3.3	6.2	3.3
X66	21.8	13.8	0.5	-1.0	-3.3	-1.3	1.0	-5.3	-1.3	-0.5
sd	4.5	4.4	7.0	5.9	5.3	4.1	6.9	4.0	5.4	4.0
X68	19.3	11.0	1.5	-2.8	0.0	-2.5	0.3	2.8	1.8	2.0
sd	4.5	5.7	6.0	5.4	6.6	5.2	7.2	5.6	6.8	5.7
X55	19.5	9.3	-4.3	-3.8	-0.8	0.8	1.8	1.3	3.5	5.8
sd	5.3	4.5	5.5	5.2	5.8	5.8	7.6	4.4	5.4	3.3
GP av	20.6	11.4	-0.2	-1.6	-0.2	-0.5	-0.1	-0.7	1.5	1.1
GP sd	1.1	3.0	5.6	4.5	3.1	2.6	3.3	7.5	2.8	6.7

results are based on 20 repeated determinations of threshold for each subject. Table 2 contains the corresponding results from the pure tone audiometry for the same subjects. The number of pure tone thresholds for each subject is indicated since not all subjects were tested 20 times. Table 3 contains F ratios resulting from dividing the variance of the pure tone thresholds by the variance of the one-third octave band thresholds. These F-ratios have 19 degrees of freedom (DF) in the

Table 2.
Average values and standard deviations of the thresholds determined using pure tone stimuli.

Frequency in kHz

Subject	0.125	0.250	0.50	1.0	1.6	2.0	3.1	4.0	6.3	8.0
X63	21.8	5.3	-3.3	0.3	-4.3	-2.5	3.0	-3.5	-1.0	-0.5
sd	7.5	6.4	6.6	8.6	10.3	8.2	9.7	6.2	8.2	7.6
X64	17.5	2.5	-5.8	-8.8	-5.0	-2.8	1.3	-2.3	1.5	-2.3
sd	4.5	8.1	6.8	4.7	5.8	6.8	4.7	6.4	9.0	6.6
X66	22.8	6.5	-7.5	-3.5	0.2	-6.5	-3.2	-2.2	1.5	1.8
sd	5.3	3.7	5.2	3.7	5.4	4.9	6.5	5.3	8.0	7.5
X68	19.8	9.5	-3.2	-6.2	1.2	-3.8	1.5	0.5	1.5	7.2
sd	10.1	3.1	7.3	5.0	5.3	5.6	5.8	8.1	6.9	5.9
X55	17.5	-1.6	-1.1	-5.2	-10.2	-5.7	2.0	4.8	-2.0	4.3
sd	7.7	8.7	7.1	5.8	2.5	6.5	7.5	7.2	6.2	6.1
GP av	19.9	4.4	-4.2	-4.7	-3.6	-4.3	0.9	-0.5	0.3	2.1
GP sd	4.7	14.1	4.9	9.0	16.6	2.5	4.5	8.7	2.3	11.3

denominator and the numerator DF are as indicated in the table. Large values of F indicated the one-third octave band thresholds are more reliable. The F-ratio is significant at the 0.05 level in 13 cases out of 50, or 26 percent of the cases. Inverting the F-ratios will test for the cases where the pure tone thresholds are more reliable. The F-ratios are significant at the 0.05 level in three cases, or only 6 percent of the cases. This overall pattern of variance ratios indicates that the audiometric procedure using one-third octave bands represents some improvement in the test-retest reliability of the thresholds. This effect is most pronounced in subject X63 that showed increased reliability at most frequencies. In contrast, subject X68 showed no improvement in reliability with the one-third octave band stimuli.

Figure 1 compares the average audiograms determined by the two procedures. Since the one-third octave band stimuli are relatively narrow band, we would expect the band levels at threshold to agree with the pure tone levels at threshold. Generally, the agreement is fair. There are a few frequencies at which the thresholds seem to differ, e.g., 0.25 through 2.0 kHz; however, these differences are not large (4 to 7 dB). An analysis of variance (Winer, 1962) was used to test for equivalence of the average audiograms determined by the two methods. The main effect for stimulus type was significant at the .05 level, indicating there was a difference in the SPL at

Table 3
F-ratios formed by dividing the test-retest variance of thresholds determined using pure tone stimuli by thresholds determined using one-third octave bands of noise.

Frequency in kHz

Subject	0.125	0.250	0.50	1.0	1.6	2.0	3.1	4.0	6.3	8.0	ndf
X63	0.71	2.39*	2.47*	2.19*	3.28*	2.09	6.77*	0.85	1.12	4.18*	19.00
X64	1.08	1.79	1.85	0.71	1.20	4.77*	0.94	3.68*	2.11	3.91*	19.00
X66	1.36	0.71	0.55	0.40#	1.05	1.40	0.90	1.74	2.16	3.51*	14.00
X68	4.97	0.28#	1.45	0.87	0.65	1.15	0.66	2.12	1.04	1.08	14.00
X55	2.07	3.70*	1.64	1.23	0.19#	1.27	0.97	2.62*	1.33	3.52*	10.00

Notes:

1. ndf: numerator degrees of freedom denominator degrees of freedom were 19
2. * 1/3 octave band thresholds significantly more reliable at the .05 level
3. # pure tone thresholds significantly more reliable at the.05 level

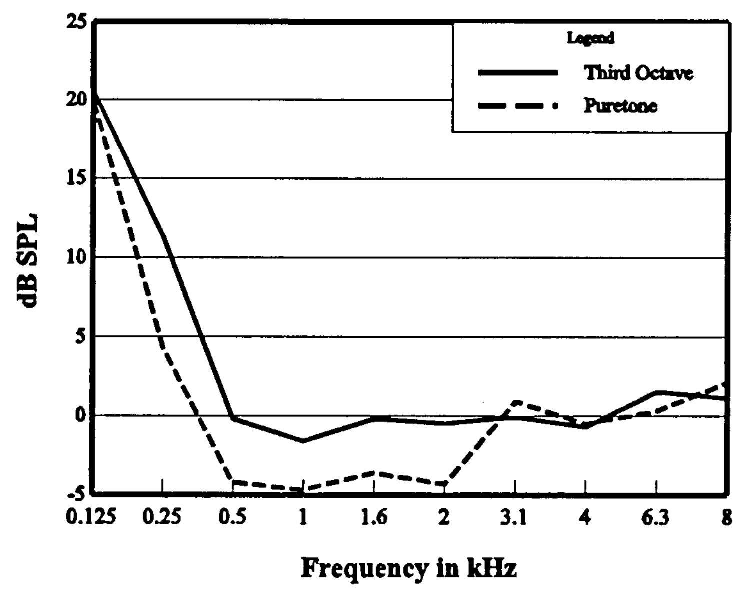

Figure 1. Average threshold in sound pressure level determined using pure tone and 1/3 octave bands of noise stimuli.

threshold between the two types of audiograms. In addition, the frequency by stimulus type interaction was significant indicating the differences were not consistent at all frequencies.

Conclusions

The audiograms determined using one-third octave bands of noise in a quasireverberant sound field are at least as reliable as the conventional pure tone audiograms for the chinchilla. The sound pressure levels at threshold are different at least at some frequencies.

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