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Measuring human aversion to sound without verbal descriptors

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High school students tapped rapidly on a telegraph key to reduce the intensity of a continuous acoustic stimulus presented through earphones. Failure to respond resulted in an intensity increase of 1 dB every 4 sec. In Experiment 1, a group of 19 students responded to three pure tones (125, 1,000, and 8,000 Hz) and a white noise. The different asymptotic levels observed after 4 min were taken as a measure of equal-aversion levels for the stimuli. In Experiment 2, the effect of the starting intensity level (45, 70, and 90 dB SPL) was determined for a 1,000-Hz tone. Differences in the asymptotic intensity levels observed after 6 min were not significant. In Experiment 3, no significant effect was found upon varying the number of responses required to produce a 1-dB intensity decrement in a 1,000-Hz tone. Together, the experiments demonstrated the feasibility of determining equal-aversion levels for sounds.

Several studies have shown that intense sounds can serve as negative reinforcers for a variety of animals. Escape responding has been maintained by means of intense noise stimuli in cats (Barry & Harrison, 1957) and in mice (Barnes & Kish, 1957). Using rats as Ss, numerous experimental studies have demonstrated escape and avoidance responding with a wide variety of acoustic stimuli (Lyon, 1964; Campbell & Bloom, 1965; Myers, 1967; and many others). Very few of these investigations have been concerned with the psychophysics of measuring the relative aversiveness of the various frequency components present in the acoustic stimuli. An exception is the determination made by Campbell (1957) of the aversion thresholds of rats for different bands of noise. He found that the auditory aversion thresholds for his animals were about 40 to 50 dB higher than their auditory absolute detection thresholds over a frequency range of 250-5,000 Hz.

Quite a different situation is encountered in the literature devoted to measuring the human response to intense sounds. Here the psychophysical approach dominates, resulting in a proliferation of several hundred studies. A comprehensive review of the field by Kryter (1970) lists over 900 references. A large number of these concern the relative human response to different frequency characteristics of the acoustic stimuli, including equal-loudness level, A-weighted sound level, perceived noise level, and others (see Kryter, 1970). In the vast majority of these psychophysical studies, some sort of verbal descriptor like "loud," "noisy," "unpleasant," "unacceptable," etc., has been employed to define the response required of the Ss. In addition to certain semantic inconsistencies demonstrated by Kerrick, Nagel, and Bennett (1968), the use of such verbal descriptors makes comparison with behavioral studies involving animals extremely difficult.

When the literature is narrowed to those experimental investigations of human aversion to sound that do not employ verbal descriptors, the number of studies dwindles and the general approach becomes similar to the one found in the animal aversion experiments. Azrin (1958) demonstrated that white noise at levels of 105-120 dB could maintain steady escape and avoidance responding in young soldiers. Hefferline, Keenan, and Harford (1959) obtained involuntary escape and avoidance conditioning from relaxed human Ss who were unaware of their own responding, while Lindsley (1957) even obtained motor responding to reduce sound intensity from Ss who were asleep. The punishing effects of an intense buzzer sound on the operant behavior of mental patients has been studied by Herman and Azrin (1964) and Ayllon and Azrin (1966). In determining the human response to combinations of intense lights and sounds, Eysenck (1967) reported a difference in tolerance between persons classified as extroverts and introverts on the basis of certain tests. Moreover, Ludwig (1971) found more active avoidance responding to reduce intense sounds than to reduce intense lights in similar sensory overload experiments. The present experiment was designed to demonstrate the feasibility of making a rudimentary psychophysical determination of human auditory aversion levels for sounds without the use of verbal descriptors.

METHOD

Subjects

The Ss for the three experiments reported in the present paper were 31 high school students between the ages of 16 and 19 years. The group consisted of 17 males and 14 females, all of whom volunteered as part of the summer aids program conducted annually by the National Bureau of Standards. Each S was otologically normal, as tested with continuous pure tones on a Békésy-type recording attenuator. Thresholds were referred to the International Organization for Standardization (ISO, 1964) R/389. They received their normal salary of $1.60/h.

Apparatus

The signals were generated by three oscillators (125, 1,000, and 8,000 Hz) and a white-noise generator. The noise generator produced a random electrical noise of a constant spectrum level from 10 to 10,000 Hz (3 dB down). Each source could be switched into an audio circuit containing appropriate amplifiers and attenuators, followed by a recording attenuator operating in discrete 1-dB steps under the control of programming logic. The electrical signals were fed to a pair of Beyers DT48-S earphones outfitted with Beyers supra-aural cushions.[1] The earphones were calibrated both before and after the experiment on an NBS-9A coupler in accordance with American National Standards Institute (ANSI, Z24.9). The PTB adaptor designed especially for the above coupler was employed. The rms voltage across each earphone was periodically monitored during the experiments and maintained stable to within 0.5 dB. Although listening was diotic, the sound pressure levels (SPL) reported are for a single phone, referred to 20 μPa (20 $\mu N/m^2$). Throughout the experimental sessions, the S sat in a sound-attenuating chamber meeting American National Standards Institute (ANSI, 1960) S3.1 requirements.

Procedure

The Ss read instructions explaining their task. In Experiment 1, a group of 19 Ss was instructed to work on anagram games, while in Experiments 2 and 3, a group of 12 Ss (6 in each experiment) was instructed to work on a programmed textbook on English usage (Blumenthal, 1972). The instructions stated that a $10 bonus would be offered to the S who either circled the most nouns in the case of the anagram games or who achieved the highest score on a final quiz in the case of the English material. In addition, the instructions explained the following conditions: (1) the Ss had to wear the earphones; (2) they could, however, tap rapidly on the telegraph key in order to obtain decrements in sound intensity; and (3) if they did not tap, the sound intensity would gradually increase. The instructions also stated that tapping on the telegraph key was a part of their task. Nevertheless, during the first session, many Ss had to be verbally coaxed to tap more rapidly in order to obtain initial reinforcements. No other verbal descriptors regarding the sounds were mentioned.

The Ss responded on a second-order schedule of reinforcement designed to produce a rapid rate of tapping on the telegraph key. A differential reinforcement of high rate (DRH) component required that a response be made within 200 msec of a previous response before it counted toward earning a reinforcement. A fixed ratio (FR) component required that 2, 10, or 20 responses meeting the DRH criterion be made before a reinforcement was delivered. The reinforcement consisted of a 1-dB decrement in the sound intensity. If the S failed to respond, the sound intensity increased 1 dB every 4 sec according to a free-running clock. However, if the S had responded 200 msec or less before the intensity increment was scheduled to occur, no increment was delivered. This latter contingency eliminated rapid reversals in the direction of intensity changes that could not be handled by the equipment. Similar schedules of reinforcement have been used successfully in the past to maintain a high rate of responding in escape and avoidance situations (Lindsley, 1957; Boren & Malis, 1961).

In Experiment 1, the Ss were presented with one of four different acoustic stimuli: a 125-, 1,000-, or 8,000-Hz pure tone, or a white noise. Each stimulus was present during four 10-min sessions, arranged in a counterbalanced order and randomly assigned to the Ss. The starting intensity levels were 87, 70, 77, and 70 dB SPL for the four stimuli, respectively. These intensity levels were within 5 dB of an A-weighted sound level of 70 dB for each stimulus. The FR component of the schedule remained fixed at 20 responses. Experiments 2 and 3 were conducted 1 year after Experiment 1. The stimulus for these latter experiments was always a 1,000-Hz pure tone presented during 18 sessions lasting 15 min each. In Experiment 2, the starting intensity level was randomly set at 45, 70, or 95 dB SPL for six Ss (6 sessions at each level in a counterbalanced order). The FR component for this experiment was 10 responses. In Experiment 3, the starting intensity level was always 70 dB SPL for a different group of six Ss. However, this time the FR component of the schedule was changed (FR = 2, 10, or 20) for different sessions. Six sessions at each ratio were completed by each S, who was randomly assigned to one of the counterbalanced session orders. Throughout all three experiments, the upper intensity limit for which the sound-level-increment portion of the schedule was in effect was 110 dB for an A-weighted sound level. Some of the Ss allowed the intensity level to reach this limit during the first few sessions. Since the intensity level increased no further, the Ss could cease responding entirely and still maintain a constant sound level. In order to assure similar reinforcement contingencies for all the Ss, those Ss who reached this intensity limit were told to continue to tap on the telegraph key to maintain control over the sound at all times even though the level was near the limit of the equipment. Less than one-quarter of the Ss needed to be given these additional verbal instructions.

RESULTS

The results of Experiment 1 are presented in Figs. 1 and 2. In Fig. 1, the average maintained SPL across stimuli and replications is shown as a function of time for each of the 19 Ss. The lowest curve, which is not shown in its entirety, stabilized after 4 min at an SPL of about 26 dB. In general, most of the other curves likewise became asymptotic after about 4 min. Complete data were available for only the first 7 min of each session, but inspection of available data over the entire 10-min session revealed that the displayed SPL values were generally maintained until the end of the session. Thus, the data were collapsed or averaged over the asymptotic interval from 4-7 min to obtain a single estimate of the asymptotic SPL value. These single estimates are given to the right of the various figures. For example, in Fig. 1, the grand mean for the maintained SPL across Ss, stimuli, and replications was 76.4 dB over the interval from 4-7 min.

In Fig. 2, the average maintained SPL across Ss and replications is shown for each of the four stimuli. Each data point represents the mean of 76 measurements, with selected standard errors for these means indicated by vertical bands. The asymptotic maintained SPL associated with each stimulus over the interval from 4-7 min is given to the right of the figure. Within the arcs along the ordinate radiate the slopes of the intensity changes that would result from different mean rates of responding by the Ss. The arcs reveal that a S could maintain a constant SPL with a tapping rate of 4 responses/sec. This rate of responding can be regarded as titrating the given schedule of reinforcement, since the S's responses just offset the intensity increments.

Inspection of Fig. 1 shows that most of the Ss responded by first achieving a certain sound level and then maintaining that level by titrating the schedule. The schedule was extremely sensitive to small changes

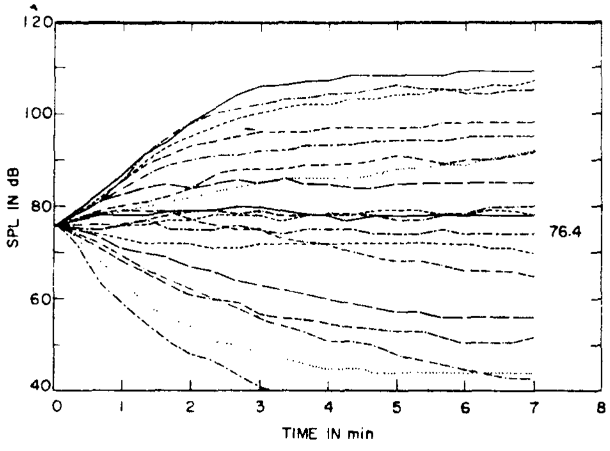

Fig. 1. Average maintained SPL as a function of time for 19 Ss in Experiment 1. The asymptotic grand mean SPL in dB is given to the right. S averages are across all four stimuli.

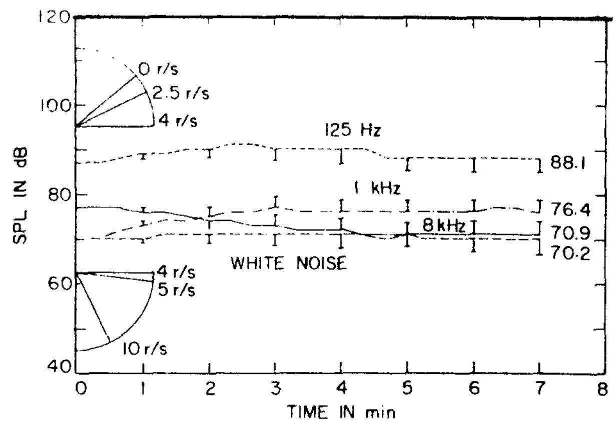

Fig. 2. Average maintained SPL as a function of time for four stimuli in Experiment 1. Bands denote one standard error of the mean, with asymptotic SPL values in dB indicated to the right. The arcs describe schedule contingencies.

in responding rate around this titration value. For example, the one S (dotted curve) who allowed the average sound level to steadily, but slowly, increase 15 dB over the entire 7-min period depicted in Fig. 1 emitted an average of 1,176 responses over that period. By contrast, the one S (short- and long-dashed curve) who maintained a constant SPL of 76 dB over the entire 7-min period emitted an average of 1,260 responses, a difference of only 84 responses.

A two-way analysis of variance was performed on the data collapsed over the 4-7-min interval. The effects of both Ss and stimuli were significant: $F(18,228) = 46.61$, $p < .05$, $\omega^2 = 0.67$; and $F(3,54) = 26.72$, $p < .05$, $\omega^2 = 0.07$, respectively. The interaction effect was not significant. Thus, the group of Ss did respond differentially to the various stimuli, and individual Ss did respond with significantly different maintained SPLs. Since the interaction effect was not significant, different people on the whole, did not respond in a significantly different manner to the various stimuli. Most of the differences among individuals came from an overall raised or lowered maintained level for all the stimuli. Inspection of individual data confirmed this conclusion.

The results of Experiments 2 and 3 were analyzed in a somewhat different manner. Since both the starting intensity level and the number of responses required by the schedule were being varied, it was important to obtain stable pressing behavior on the telegraph key. Thus, the first six sessions (two for each condition) were regarded as practice sessions, and data from only the last 12 sessions (4 for each condition) were included in the analysis. In Fig. 3, the average maintained SPL across all conditions and across the last four replications is shown as a function of time for each of the 12 Ss in Experiments 2 and 3 combined. Complete data were available for only 12 min of each session, with the loss of only two measurements from 12-14 min. Two Ss from Experiment 3 (M.G. and K.T., with dots along the curves) exhibited atypical behavior, and their data were removed from further analyses. The grand mean across the remaining 10 Ss was 72.2 dB for the interval from 6-12 min. The four Ss whose data were included in the analysis of Experiment 3 are identified in the caption of the figure.

The results of Experiment 2 are shown in Fig. 4. The solid curves represent the average SPL maintained by the group of six Ss to a 1,000-Hz tone initially presented at three different intensity levels. Each data point represents the mean of 24 measurements, with standard-error bands indicated every minute. The arcs to the left of the figure reveal a

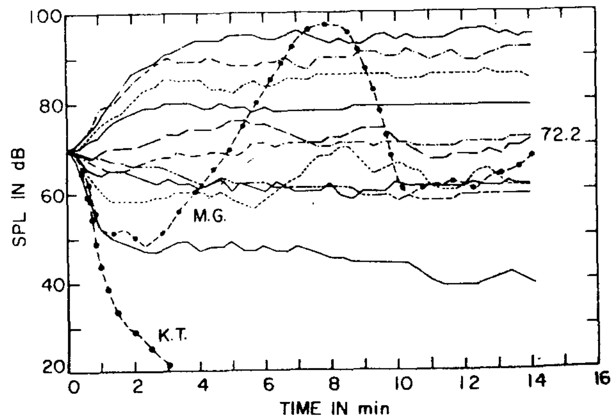

Fig. 3. Average maintained SPL as a function of time for 12 Ss in Experiments 2 and 3 combined. The asymptotic grand mean SPL in dB for 10 Ss (excluding M.G. and K.T. from Experiment 3, with dots along their curves) is given to the right. The following curves represent the data from the four remaining Ss in Experiment 3: the second solid curve from the bottom, the lowest short-dash curve, the only remaining long-dash curve, and the highest short- and long-dash curve.

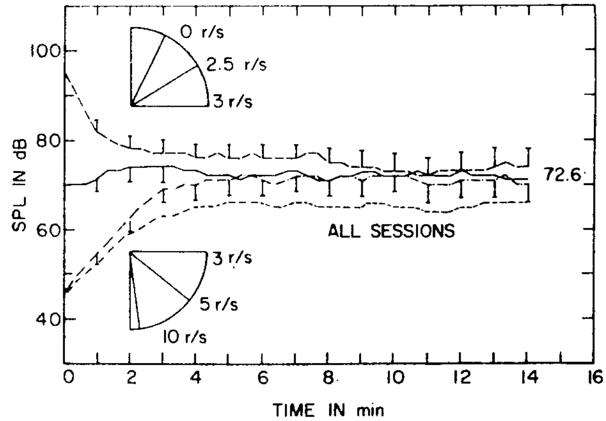

Fig. 4. Average maintained SPL as a function of time for the three different starting intensity levels employed in Experiment 2. The three upper curves depict means for the last 12 sessions only, with bands denoting one standard error of the mean. The asymptotic grand mean SPL in dB for these three curves combined is given to the right. The lower curve depicts data for the 45-dB starting intensity level when all sessions were considered, including training sessions. The arcs describe schedule contingencies.

titration rate of 3 responses/sec. The grand mean across all Ss, conditions, and replications was 72.6 dB SPL over the interval from 6-12 min. When the data for all 18 sessions of Experiment 2 (including the practice sessions) were considered, the results were similar to those depicted by the upper curves in Fig. 4. In the case of the 95- and 70-dB starting intensity levels, the means for 18 sessions and for 12 sessions always differed by less than one standard error of the mean. In the case of the 45-dB starting intensity level, the average maintained SPL for all 18 sessions was somewhat lower, as indicated by the lowest dashed curve in Fig. 4.

The data for the last 12 sessions of Experiment 2 were collapsed over the interval from 6-12 min as in Experiment 1. An analysis of variance disclosed a significant effect of Ss: $F(5,54) = 108.39$, $p < .05$, $\omega^2 = 0.87$. Neither the effect of starting intensity level nor the interaction effect was significant. Thus, although there were significant differences in the maintained SPL values for different Ss, the average curves for the various starting intensity levels converged toward a single asymptotic maintained value after about 6 min.

The results of Experiment 3 are given in Fig. 5. The average maintained SPL across four Ss and across the last four replications is shown as a function of time for the three different FR components of the schedule. The curves represent the means of 16 measurements with standard-error bands for these means depicted at 1-min intervals. The arcs portray the slopes of intensity changes that would be expected for different tapping rates on the various schedules. The asymptotic maintained SPL in decibels over the interval from 6-12 min is indicated to the right of the figure for each schedule. An analysis of variance, similar to that of Experiment 2, disclosed once again a significant effect of Ss, $F(3,36) = 6.65$, $p < .05$, $\omega^2 = 0.25$. Neither the effect of schedules nor the interaction effect was significant. Thus, the results of Experiment 3 show that, despite significant differences in the average SPL maintained by the four different Ss, changing the number of responses required by the schedule had no significant effect on that average maintained SPL value. Although the effect of changing the amount of effort was not significant, a trend toward higher maintained levels for increasing effort did appear among the curves in Fig. 5. If the six practice sessions for each of the four Ss had been included in the analysis, this trend would have been significant ($p < .05$). Thus the lack of a significant schedule effect for experienced Ss is a result that should be regarded with some caution.

The performance of the Ss on the anagram task did not show any consistent variation with the different acoustic stimuli. Nor did the individual anagram performance correlate significantly with the final asymptotic level achieved by each S. In the latter instance, the product-moment correlation coefficient between the total number of nouns circled during Experiment 1 and the average maintained SPL for all the stimuli was 0.11, which was not significant ($p > .05$).

DISCUSSION

The results of the present study demonstrate the feasibility of making rudimentary psychophysical determinations of human auditory aversion levels. Experiment 1 showed that, for different acoustic stimuli, the average maintained SPL became asymptotic after about 4 min, permitting a stable

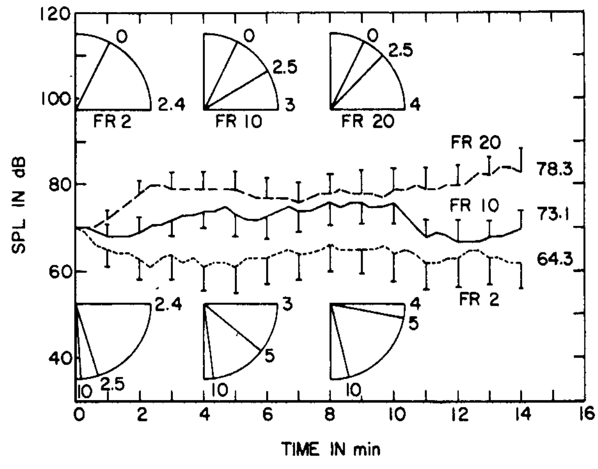

Fig. 5. Average maintained SPL as a function of time for three different FR components in Experiment 3. Bands denote one standard error of the mean, with asymptotic SPL values in dB indicated to the right. The arcs describe schedule contingencies.

measurement of the aversion threshold. However, the results of Experiment 1 also revealed little change in the average maintained SPL from the starting SPL presented at the beginning of the session. Conceivably, the average maintained SPL could be an artifact of the starting intensity level. Such a hypothesis was not confirmed by the results of Experiment 2, where the starting intensity level was varied over a range of 50 dB. Irrespective of the starting intensity level, the average maintained SPL converged upon a single estimate of the aversion threshold after about 6 min. A third factor that is relevant is the sensitivity of this particular technique for measuring aversion thresholds to changes in the schedule of reinforcement. The results of Experiment 3 suggest that the methods employed in the present study are relatively insensitive to schedule changes. When the FR component of the schedule was varied by a factor of 10, no significant change was apparent in the aversion threshold. This latter finding, however, was based upon the data from only four Ss (16 observations).

The three experiments reported in the present study, conducted over a span of more than 1 year with different groups of Ss, afforded several opportunities to determine the repeatability of the observations. The asymptotic maintained SPL values obtained from all three experiments are presented in Fig. 6 for intercomparison. The open circles represent the SPLs for the three pure tones employed in Experiment 1, where the FR component was fixed at 20 responses. The filled circle represents the SPL for the FR = 20 component schedule employed in Experiment 3. The two squares represent data collected with an FR = 10 component. The filled square is from the FR = 10 component in Experiment 3, while the open square represnts the single estimate of the asymptotic maintained SPL for all starting levels in Experiment 2. At least in the case of the 1,000-Hz tone, the rather close correspondence of the various determinations, especially those employing the same schedule, attests to the possibility of obtaining comparable data upon repeating the experimental procedure with different Ss.

The asymptotic maintained SPL values for the different frequencies in Experiment 1 could be regarded as equal-aversion levels under the given schedule of reinforcement. As such, they could convey some psychophysical information about the relative human tolerance for the different frequency characteristics of the stimuli. These equal-aversion results could then be compared with other determinations of constant human response as a function of frequency. Such a comparison is presented in Fig. 6. The curve connecting the open circles represents the measurement of equal-aversion levels

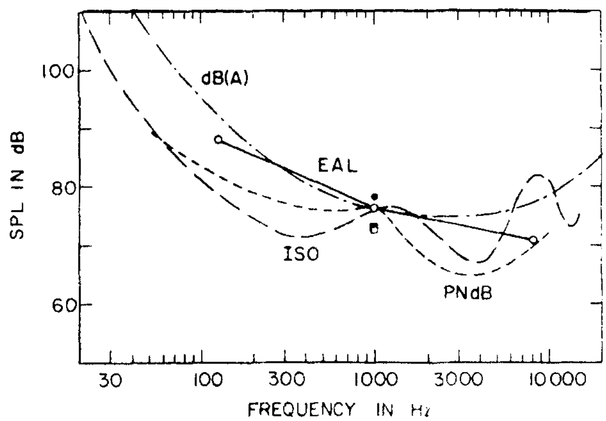

Fig. 6. Sound pressure level for an equal human response as a function of frequency. Equal aversion levels (EAL) for the three pure tones in Experiment 1 are shown as open circles. Replications of aversion thresholds from Experiments 2 and 3 are shown by the remaining data points at 1,000 Hz. Other curves representing previous determinations of equal human response are included for comparison.

(EAL) for the three pure-tone stimuli in Experiment 1. For comparison, the A-weighted sound level has been drawn from American National Standards Institute (ANSI, 1971) S1.4. This dB(A) weighting corresponds to a 40-phon equal-loudness level. Since the various EAL determinations of the present study were closer to a 75-phon level, the 75-phon equal-loudness contour from International Standardization Organization (ISO, 1961) R/226 is also shown. Both of these comparison curves are derived from psychophysical experiments using "loudness" as a verbal descriptor for pure-tone stimuli. In addition, the appropriate perceived noise level (PNL) curve for 75 PNdB has been included from the Federal Aviation Regulations (FAA, 1969). This PNdB curve is based upon relative determinations employing the verbal descriptor "noisy" to narrow bands of noise. All curves have been normalized for 76 dB SPL at 1,000 Hz. As is evident in the figure, the rudimentary measurements of equal aversion levels obtained in the present study fall between the A-weighted sound level and the other contours.

Finally, the results of the present study may be compared with measurements made by Campbell (1957) of the auditory aversion threshold for rats. The aversion thresholds for rats were generally 10-20 dB higher than those for humans, and the aversion level curve as a function of frequency was somewhat steeper for rats than for humans. Whereas Campbell found a correspondence between the shapes of the auditory aversion threshold and the auditory detection threshold for rats, no such correspondence was suggested in the data from humans (see ISO R/389).

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NOTE

1. Certain commercial equipment, instruments, or materials are identified in this paper in order to specify adequately the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

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