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SOME RELATIONS BETWEEN NORMAL HEARING FOR PURE TONES AND FOR SPEECH

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This experiment was designed to determine the intensity difference between normal hearing for spondee words and normal hearing for a 1000 cps pure tone.

A preliminary investigation indicated that sophisticated listeners achieved considerably lower spondee threshold sound pressure levels than unsophisticated listeners, in spite of essentially equivalent pure-tone threshold sound pressure levels.

The main experiment, employing 96 young adults with normal hearing, investigated the five factors of threshold determination, order of test administration, sex, ear, and familiarity with test vocabulary. Only familiarity with test vocabulary exerted a major influence on threshold response, yielding sound pressure levels about 3 db lower for those subjects given prior knowledge of spondee vocabulary.

The results indicate that an intensity difference of 12-13 db between thresholds for a 1000 cps pure tone and for speech is approximately medial for normal-hearing subjects. It represents a value which might properly be selected as the relationship to be specified for audiometric standards.

INTRODUCTION

Serious confusion exists as to the difference between the sound pressure levels which characterize the normal threshold for a 1000 cps pure tone and the normal threshold for speech. Estimates as to the size of this discrepancy disagree by as much as 10 db. In consequence, there is need for clarification of the situation since the relationship between these two thresholds must be taken into account in establishing coordinated audiometric standards.

The problem at hand is quickly apparent when one compares the norms as presently described by the American standards for audiometers with the findings of various studies reported in the literature. The American Standard Specification for Audiometers for General Diagnostic Purposes (1) defines the normal threshold sound pressure level for 1000 cps as 16.5 db (SPL referred to 0.0002 microbar in a National Bureau of Standards coupler 9-A), for the Western Electric type 705-A earphone. The American Standard Specification for Speech Audiometers lists 22 db (SPL referred to 0.0002 microbar in an American Standard type-1 coupler) as the norm for speech. Indeed, the specification explicitly states that "... the purpose of this requirement [22 db SPL] is to set the 0 hearing loss for speech at a level about 6 *db* [italics ours] above the "normal" [sic] threshold for a pure tone of 1000 cps as defined in American Standard Audiometers for General Diagnostic Purposes . . ." (2, p. 9). The specification further implies that the 6 db difference is recognized as an approximation which may require revision.

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Sporadic evidence (3-7) suggests that the difference in question is considerably greater than 6 db. Davis (5), for example, reports the average of the thresholds for 500, 1000, and 2000 cps as 9 db (SPL) at the same time that he gives thresholds for various speech materials which range from 22 db for spondees, through 26 db for sentence material and digits, to 33 db for PB words as spoken by Rush Hughes. Lightfoot et al. (7) observed a 16.5 db difference between the threshold intensities for 1000 cps and for spondee words exhibited by 31 otologically normal subjects. The most definitive finding to date, however, is derived from the 1954 Wisconsin State Fair Survey (6). Here, the difference between the averages of the median threshold values for a 1000 cps pure tone and for spondee words, reported for all ears in the "selected normal group" was 15 db. Discrepancies of relatively similar size characterize the results obtained in the survey for samples (by decades) of the general population, although the data as presented must be converted to sound pressure levels before the fact is fully apparent. Most recently, there is the indirect evidence to be derived from Corso's (3, 4) studies of normals' thresholds for pure tones and for CID Auditory Test W-2. On relatively large groups of normal listeners, he obtained threshold SPLs of about 5 db for a 1000 cps pure tone and approximately 19 db for the W-2 spondee recording. These data imply that the difference between thresholds is on the order of 14 db.

Recent evidence (3, 4, 8, 9), particularly the work of Dadson and King (10) in England, has made it imperative to ask whether the present American norms for pure tones are correct. There is pressure in many quarters to alter these norms as a requisite step toward establishment of an international standard for pure-tone audiometers. This situation, among other things, intensifies the need to define the relation between thresholds for pure tones and for speech.

It is now clearly apparent from evidence such as that obtained in the Wisconsin State Fair Survey (6) that young adults yielded better thresholds than a less select group of "normal" listeners derived from the population at large. Moreover, the present American norm for speech (22 db SPL) apparently represents performance of selected young adults (the so-called "laboratory ear"). The American norm for pure tones, on the other hand, is based on the responses of a less restricted sampling (11). Here the "man on the street with 'normal' hearing" served as the referent. Thus, the two current American standards seem to be in disagreement as to the category of normalcy on which they rest. If so, the situation must be rectified by relating both sets of audiometric specifications to the same criterion population.

The first step toward such a unification of audiometric standards is to define the difference in intensity between thresholds for pure tones and for speech. Particularly pressing in this respect, since the sound pressure level of a speech signal is defined in terms of the sound pressure level of an equivalent 1000 cps pure tone (2), is the need to know the relative acuity for speech and for 1000 cps.

The present investigation was undertaken to explore the latter question. The experimental problem was to ascertain the physical discrepancy between thresholds for a 1000 cps pure tone and for speech. The specific procedure was to measure both thresholds in the same normal-hearing subjects. Recorded spondees were employed as the speech material. Variables suspected of having a critical influence on the relationship between the two thresholds were examined. These variables included sophistication of the listener, effect of practice, method of threshold determination, order of test administration, sex, ear, and familiarity with test vocabulary. Two groups of 10 subjects each were compared in examining the first two variables, while a third group of 96 subjects was used in a counter-balanced routine designed to study the remaining five variables.

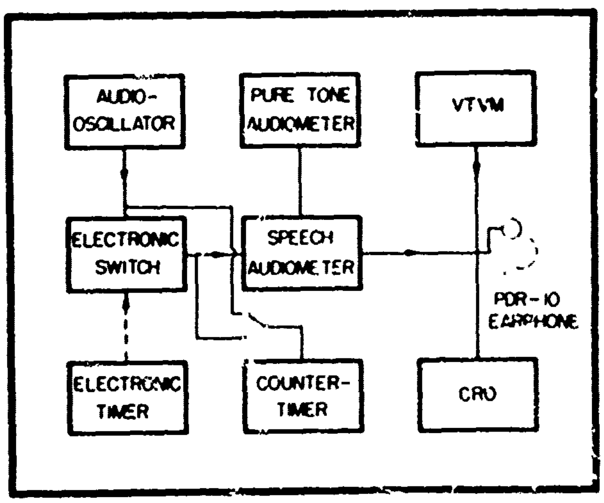

FIGURE 1

APPARATUS

Figure 1 shows a simplified block diagram of the experimental apparatus used to measure both pure-tone and spondee thresholds. The core of the equipment consisted of a commercially available speech audiometer (Grason-Stadler, type 162) feeding a PDR-10 earphone mounted in an MX41/AR cushion. All spondee thresholds were obtained by playing either recorded list E or recorded list F of CID Auditory Test W-1 through this speech audiometer.

Two separate pure-tone sources were fed through the speech audiometer to the same PDR-10 earphone. One source consisted of an audio-oscillator (General Radio, type 1304A) whose output was controlled by an electronic switch (Grason-Stadler, type 829). The electronic switch was, in turn, triggered by an electronic timer (Grason-Stadler, type 471), to produce the desired temporal pattern of the pure-tone stimulus. Stability of both the oscillator frequency and the duration of each short tone passed by the switch was assured by continuous monitoring of both oscillator and switch outputs with a counter-timer (Berkeley, type 5500). The pure-tone source described above was used to measure the 1000 cps threshold by a rigidly defined psychophysical procedure described below. The second pure-tone source was an ordinary pure-tone diagnostic audiometer (ADC, model 53C). This source was used to measure the 1000 cps threshold by the "clinical" method which was studied.

The electrical signal across the earphone was monitored with a vacuum-tube voltmeter (Hewlett-Packard, model 400C) and a cathode-ray oscillograph (Dumont, model 304-A).

The acoustic output of the apparatus was calibrated by means of an ASA type-1 coupler, calibrated condenser microphone (Western Electric, type 640AA), cathode follower (ADC, D5153) and vacuum-tube voltmeter (Hewlett-Packard, model 400-A). All thresholds, both pure tone and speech, are thus subsequently reported as the sound pressure level, referred to 0.0002 microbar, developed in an ASA type-1 coupler.

The sound pressure level developed by the earphone at 1000 cps was measured daily throughout the course of the experiment. The maximum variation in output over the five-month period during which subjects were tested was 1.4 db, and the day-to-day variation exhibited no systematic trend over time. Pressure levels developed at octave frequencies from 125 to 3000 cps were measured weekly over the five-month period, and demonstrated equivalent stability.

Prior to the experiment, precautions were taken to insure that the speech audiometer conformed to all requirements listed in the American Standard Specifications for Speech Audiometers (2) with particular reference to tests of over-all acoustic fidelity. The apparatus equaled or exceeded all listed specifications.

THRESHOLD MEASUREMENT TECHNICS

In order to evaluate the possible effect of threshold measurement technic on the relationship between pure-tone and speech thresholds, two separate and distinct methods for defining each type of threshold were employed. One, the "up-and-down" method (12) was characterized by a relatively rigidly defined set of operations. The other, hereafter called the "clinical" method, was an attempt to duplicate the procedures commonly employed by audiologists within the context of the clinical situation.

Up-and-down method

This method was selected in preference to any of the three classical psychophysical methods or their variants because it permitted a relatively identical stimulus temporal pattern and measurement procedure for both pure-tone and speech thresholds. The essence of the method is that the intensity level of each successive stimulus is determined by the subject's response to the previous stimulus. If the subject does not respond at a particular intensity, the next level of the stimulus is *increased* by a predetermined fixed amount. On the other hand, if the subject does respond at a particular intensity, the level of the next stimulus is *decreased* by the same amount. This simple rule, raising the intensity when the subject does not respond and lowering it when he does respond, is followed throughout the course of a predetermined number of stimulus presentations. The result is a series of response measures which oscillate about the threshold intensity. From these data, the intensity level corresponding to 50 percent response may be determined by suitable arithmetic computation (12).

In the present experiment the intensity levels of successive stimuli were altered in 2 db steps over a series of 36 presentations. For the spondee threshold, the block of successive stimuli consisted of the 36 spondee words recorded as lists E or F of CID Auditory Test W-1 (Technisonic Studio's Recording). For the 1000 cps threshold, the stimulus sequence was a train of 36 short tones recurring at 6-second intervals. Each short tone had a rise-decay time of 50 milliseconds, and a duration, at maximum amplitude, of 500 milliseconds. The 6-second repetition rate for the pure tones was selected to match the rate at which the spondee words recur on the W-1 recordings. Thus, insofar as thresholds obtained by the up-and-down method are concerned, the experimental procedure was virtually identical for both pure-tone and spondee thresholds. The only difference was that for the spondee threshold each stimulus was a word which the subject repeated, either correctly or incorrectly, while for the 1000 cps threshold each stimulus was a pure tone to which the subject either did, or did not respond.

Clinical method

Devising a satisfactory analog to so-called "clinical audiometric technic" proved to be one of the more difficult problems encountered in this investigation. Numerous sources were consulted in an attempt to find some common denominator epitomizing the basic operations to be followed in the clinical measurement of an auditory threshold. The relatively small number of even cursorily described procedures found in the literature were characterized by a certain lack of agreement on some relevant particulars (e.g., the number of times a stimulus is presented at a given level, whether a pure-tone stimulus is briefly turned on or briefly turned off, whether the threshold criterion is 100 percent response, 50 percent response, 0 percent response, or some intermediate value).

Briefly, it seemed apparent that, in order to introduce some minimal degree of objectivity into our "clinical" thresholds, it was necessary to devise our own method. In so doing, we attempted to follow, as closely as possible, the counsel of experienced clinicians. It would be less than completely honest to deny, however, that in the final analysis the authors are able to justify the "clinical" procedures ultimately employed on the sole basis that they seemed reasonable to them.

The clinical procedure adopted for the measurement of the spondee threshold corresponded closely to the method described by Newby (13) for the W-1 records. Two or three words were initially presented at a level 20-30 db above the estimated threshold level. Successive blocks of two to three words were then progressively attenuated in 10 db steps until a level was reached at which two consecutive words were repeated incorrectly. At this point, the tester simply "jumped around," in no set order, from level to level in 2 db steps, presenting exactly four words per level. The spondee threshold was recorded as the lowest intensity at which the subject repeated two out of four words correctly. In the event that the subject repeated three out of four words correctly at one level, and only one out of four correctly at the next lower level, threshold was recorded at the intensity yielding three out of four responses. This problem seldom arose in actual practice.

The clinical procedure employed to measure the 1000 cps threshold closely resembled the "ascending" technic described in the 1951 revision of the *Manual for School Hearing Conservation Programs* (14) prepared by the Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology. By means of the interrupter switch on the clinical audiometer, a brief tone was first presented at a level 30 db above the estimated threshold in order to familiarize the subject with the test signal. The tester then descended in 10 db steps, presenting one brief tone at each level, until the subject failed to respond. The tester next ascended in 5 db steps, presenting one brief tone at each level, until a response occurred. He then decreased the intensity by 10 to 15 db and again ascended in 5 db steps until another response occurred. This procedure was followed until the subject had responded three times at the same level. Threshold was thus defined as the lowest intensity at which the subject responded three times in ascending runs, using 5 db steps, and presenting just one stimulus per step. No attempt was made to control the duration of each tonal presentation other than to instruct the tester to keep the presentation brief. In practice, the tones were about 1 to 2 seconds long.

Instructions to each subject tested by either the clinical method or the up-and-down method were as follows:

The purpose of this study is to measure your threshold for tones and for words. Two test runs will be conducted, one using tones and one using words.

During the tone test, you will hear a short burst of sound followed by intervals of silence. Each tone will be quite short. Some will be easy to hear. Others will be very faint. Whenever you hear one of these tones, no matter how faint it is, press the button. Since the tones will be very faint, it is necessary that you listen very carefully.

When I test for your word threshold, you will hear a man's voice saying two-syllable words, such as "wigwam," "therefore," or similar words. Each word will be preceded by the phrase "Say the word."

It is only necessary for you to repeat the two-syllable word, not the phrase. Some of the words will be easy to hear. Others will be very faint. Whenever you hear a word, no matter how faint it is, repeat it out loud. You will have to listen carefully since the words will be very faint.

At the beginning of each word test, you will hear several sentences of identifying information which you do not need to repeat.

There is no set order for the two test runs. You will be told at the beginning of each test whether it is to be a word test or a tone test.

After I have placed the phones over your ears, it is extremely important that you do not move them in any way until the tests are completed. I will tell you when you can take them off. Any questions?

SUBJECTS

All subjects were audiometrically screened at a hearing level (hearing loss dial setting) of 10 db re USPHS norm at octave intervals from 125 to 8000 cps, and at 1500 and 3000 cps, in order to insure that each subject had relatively normal acuity in both ears.

As already mentioned, three groups of subjects were employed. One group consisted of 10 sophisticated listeners. These individuals were selected from the staff and the graduate student population at the Audiological Laboratory. Each was highly experienced in the task of listening for very faint signals, and all were relatively familiar with the CID revised spondee word lists. They represented essentially "laboratory ears." They were equally divided as to sex and ranged in age from 20 to 31 years.

The second group was composed of 10 undergraduate students selected on the basis of having had no previous experience as listeners in auditory tests of any kind. Nine subjects were female, the other one, male. They ranged in age from 18 to 25 years.

The third group included 96 subjects, three for each of 32 separate experimental conditions. As was true of the second group, these 96 subjects were selected from the undergraduate population at Northwestern University and met the requirement of not having had prior experience with any auditory tests. No subject was accepted who reported any history of either ear pathology or excessive noise exposure.

Prior exposure to spondee words

Subjects differed in their familiarity with the spondee words. The 10 sophisticated listeners were well acquainted with these materials, while all other subjects initially were not. However, half of the 96 persons were exposed to the spondees immediately prior to the measurement of their threshold for the words. To this end, these 48 subjects were given additional instructions as follows:

Before the word test, I will read a series of 35 two-syllable words at a level which is easy for you to hear. You are to repeat each word. These words are the same words which you will later hear in the word test; however, they will be in a different order. Since the purpose of this initial reading of the words is to make you familiar with the words, please listen carefully.

PROCEDURE AND RESULTS

Preliminary study

An initial investigation was conducted to determine the effects of sophistication in auditory tests, and of practice upon the relationship between thresholds for pure tones and for speech. It was for this purpose that the first two groups of 10 subjects were formed.

Six thresholds were obtained for each subject in a single experimental session. Four of these thresholds were for pure-tones of 500, 1000, 1500 and 2000 cps, respectively. The last two were spondee thresholds obtained separately with W-1 list E and with W-1 list F. All six thresholds, pure tone and speech, were measured by the up-and-down method previously described using 2 db steps of attenuation. Subsequent comparison of the two groups yielded information on the effect of familiarity with audiologic procedures.

Subjects in the sophisticated group underwent the foregoing procedure twice. The first run gave these subjects experience on the specific tasks involved. The results obtained during this session supplied the base of reference against which to estimate the effect of a practice session on thresholds measured by the up-and-down method.

Table I summarizes the findings of the preliminary investigation. The mean pure tone threshold sound pressure levels obtained for the sophisticated group in the first experimental session (practice session) were essentially equivalent to those obtained in the second session (test session). This was also true for the

TABLE I

*Mean pure tone and spondee (W-1) threshold sound pressure levels**
for sophisticated and unsophisticated listeners

	Sophisticated group (N = 10)		Unsophisticated group (N = 10)
	First session	Second session	
Frequency in cps 500	12.4	12.1	10.3
Frequency in cps 1000	6.8	7.3	5.7
Frequency in cps 1500	[illegible].4	6.7	7.7
Frequency in cps 2000	6.6	7.1	8.8
First spondee threshold	17.0	16.8	24.3
Second spondee threshold	16.7	16.6	21.4
Difference between first and second spondee thresholds	0.3	0.2	2.9
Mean of both spondee thresholds	16.8	16.7	22.8
Mean spondee threshold minus mean threshold for 1000 cps	10.0	9.4	17.1

*db re: 0.0002 microbar in ASA type-1 coupler.

mean spondee threshold. In addition, when the spondee thresholds for this group are considered, no difference is noted between the first and second thresholds obtained in either the practice session or the test session.

Further inspection of table I reveals that the pure tone threshold sound pressure levels are essentially equivalent for both sophisticated and unsophisticated listeners. When the spondee threshold sound pressure levels for the two groups are compared, however, it becomes apparent that the sophisticated listeners yielded much lower thresholds than the unsophisticated listeners. Furthermore, unsophisticated listeners improved an average of about 3 db from the first threshold to the second, while sophisticated listeners did not.

It seemed possible that this 3 db improvement between the first and second spondee thresholds in the unsophisticated group could be due to the fact that the subjects gained knowledge of the test vocabulary during the first test. The same reasoning would account for the lack of improvement on the second spondee threshold in the sophisticated group. In other words, the sophisticated subjects probably already had the optimum degree of familiarity with the words prior to the administration of the first spondee test so that further exposure to test vocabulary had no demonstrable effect on threshold. If this interpretation is correct, one would expect the unsophisticated group to show further improvement on successive retests with spondee words until they reached a terminal level of familiarity, equivalent to that of the sophisticated group.

The foregoing results indicated the necessity of controlling, in the main experiment, both the general factor of subject sophistication in auditory tests and the specific factor of prior familiarity with the CID revised Harvard spondee words. The decision was made to restrict the main experiment to audiologically naive listeners because such persons are more analogous to the relatively unsophisticated population encountered in clinical situations. Moreover, it was deemed particularly important, since such persons showed instability of threshold with successive exposures to test material, to explore more fully the effect of familiarity with test procedures upon threshold levels. Information on this point is essential if the variability of threshold due to retesting is to be taken into account in specifying the criterion population for audiometric norms.

Main experiment

A five-factor design was undertaken to assess the effects on thresholds for spondee words and for a 1000 cps tone of: (1) threshold measurement technic, (2) order of test administration, (3) sex, (4) ear, and (5) prior knowledge of test vocabulary. This investigation was undertaken with the third group of subjects, 96 young adults having normal hearing but lacking previous experience with auditory tests. In order to control systematically the five factors under consideration, the group was appropriately divided. Specifically, 48 subjects were tested by the up-and-down method, the other 48 by the clinical method. Within each subgroup, the spondee test was administered first to half of the subjects, the pure tone test first to the rest. The subjects were equally divided as to sex. The right ear was tested 50 percent of the time, and the left ear the remaining 50 percent. The 36 spondees were read to half of the subjects prior to measurement of the speech threshold, while the remaining subjects were not given this opportunity to familiarize themselves with the test items.

Each subject was seen in a single experimental session, during which two thresholds were measured, the threshold for a 1000 cps pure tone and the threshold for spondee words. The latter was obtained with recorded list E of CID Auditory Test W-1.

In order to visualize the effect of each factor separately, tables II through VI were prepared to present the mean 1000 cps and spondee thresholds obtained for the two categories of each factor in turn. Table II, for example, illustrates only the effect on each threshold produced by varying the method of measurement. The mean spondee threshold for subjects in the clinical method group is only 0.1 db different from the mean threshold for subject in the up-and-down method group. There is, however, a 1.7 db difference between the two methods for the 1000 cps threshold. This difference is almost the exact order of magnitude to be expected in view of the difference in size of intensity steps used in the two methods. For the spondee threshold 2 db steps were used for both the clinical and up-and-down methods. For the 1000 cps threshold, however, 2 db steps were used in the up-and-down method, but 5 db steps were used in the clinical method. A theoretic difference of 1.5 db, in the direction of lower threshold intensity for the method involving 2 db steps would therefore be predicted. This derives from the fact that when 5 db steps are used, the mean threshold is underestimated by 2.5 db, but when 2 db steps are used, the mean threshold is underestimated by only 1 db. The observed difference of 1.7 db appears to be in relatively good agreement with this theoretic expectation.

Thus, for both the spondee threshold and the 1000 cps threshold, after allowance has been made for differences in the size of intensity steps used, there appears to be very little difference between results obtained by a clinical versus a laboratory procedure.

Table III shows that there is no large or systematic effect of sex on the auditory acuity of young normals. Females average 0.7 db better

TABLE II

Mean 1000 cps and spondee threshold sound pressure levels for each method of measurement (N = 96)*

Threshold	Method	
	Up-and-down	Clinical
1000 cps	8.1	9.8
Spondee	21.6	21.7

*db re: 0.0002 microbar in ASA type-1 coupler.

TABLE III

Mean 1000 cps and spondee threshold sound pressure levels for each sex (N = 96)*

Threshold	Male	Female
1000 cps	9.3	8.6
Spondee	21.3	22.0

*db re: 0.0002 microbar in ASA type-1 coupler.

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interpret this finding as evidence that preliminary exposure of audiologically naive subjects to a list of spondee words lowers the measured threshold SPL slightly (2-3 db).

All other F-ratios obtained in the analysis of variance for spondee thresholds were too small to imply either meaningful effects due to the factors studied or interactions of importance among these factors. This situation, coupled with the totally negative findings in the companion analysis of the data on acuity for 1000 cps leads to the conclusion that systematic effects due to method of testing, sex, ear, and order of threshold measurement are either nonexistent or are so small that they are obscured by the uncontrollable variables in the investigation. In either event, the implication is clear. These four factors did not produce effects so

TABLE VII

Summary of analysis of variance for 1000 cps threshold data

Source		df	Mean square	F-ratio
Main effects				
Method	(a)	1	63.7	3.56
Sex	(b)	1	11.1	0.62
Ear	(c)	1	42.7	2.38
Order	(d)	1	61.1	3.41
Prior knowledge	(e)	1	8.9	0.50
Interactions				
a x b		1	0.1	0.00
a x c		1	30.4	1.70
a x d		1	56.1	3.13
a x e		1	4.5	0.25
b x c		1	37.0	2.07
b x d		1	16.2	0.90
b x e		1	37.0	2.07
c x d		1	0.4	0.02
c x e		1	255.5	14.26*
d x e		1	6.6	0.37
a x b x c		1	9.6	0.54
a x b x d		1	25.4	1.42
a x b x e		1	26.5	1.48
a x c x d		1	13.5	0.75
a x c x e		1	1.9	0.10
b x c x d		1	44.3	2.47
b x c x e		1	12.8	0.71
b x d x e		1	0.1	0.00
c x d x e		1	3.2	0.18
a x d x e		1	13.0	0.72
a x b x c x d		1	6.4	0.36
a x b x c x e		1	58.6	3.27
a x c x d x e		1	7.8	0.44
b x c x d x e		1	47.3	2.64
a x b x d x e		1	125.4	7.00
a x b x c x d x e		1	78.5	4.39
Within subclasses		64	17.9	

*Exceeds value required for the 1 percent level of confidence.

TABLE VIII

Summary of analysis of variance for spondee threshold data

Source		df	Mean square	F-ratio
Main effects				
Method	(a)	1	0.0	0.00
Sex	(b)	1	13.3	1.21
Ear	(c)	1	0.9	0.08
Order	(d)	1	42.8	3.89
Prior knowledge	(e)	1	169.3	15.41*
Interactions				
a x b		1	0.0	0.00
a x c		1	35.9	3.27
a x d		1	0.2	0.02
a x e		1	38.1	3.47
b x c		1	9.3	0.85
b x d		1	9.2	0.84
b x e		1	26.8	2.44
c x d		1	2.4	0.22
c x e		1	35.4	3.22
d x e		1	2.0	0.18
a x b x c		1	63.5	5.78
a x b x d		1	0.0	0.00
a x b x e		1	6.7	0.61
a x c x d		1	0.3	0.02
a x c x e		1	3.3	0.30
b x c x d		1	3.6	0.32
b x c x e		1	9.7	0.88
b x d x e		1	16.3	1.48
c x d x e		1	0.1	0.01
a x d x e		1	1.0	0.09
a x b x c x d		1	6.8	0.62
a x b x c x e		1	29.5	2.68
a x c x d x e		1	0.8	0.07
b x c x d x e		1	0.7	0.06
a x b x d x e		1	0.1	0.01
a x b x c x d x e		1	58.4	5.32
Within subclasses		64	11.0	

*Exceeds value required for the 1 percent level of confidence.

TABLE IX

Mean 1000 cps threshold sound pressure levels for each method of measurement and mean spondee threshold sound pressure levels for each method of measurement and for subjects with and without prior knowledge of spondee test vocabulary*

Method	1000 cps threshold	Spondee thresholds		
		Without prior knowledge	With prior knowledge	Combined
Up-and-down	8.1	22.3	20.9	21.6
Clinical	9.8	23.6	19.7	21.7
Combined	9.0	23.0	20.4	21.6

*db re: 0.0002 microbar in ASA type-1 coupler.

TABLE X

Difference between mean 1000 cps threshold sound pressure levels and mean spondee threshold sound pressure levels for each method of measurement and for subjects with and without prior knowledge of test vocabulary*

Method	Without prior knowledge	With prior knowledge	Combined
Up-and-down	14.2	12.8	13.5
Clinical	13.8	9.9	11.9
Combined	14.0	11.3	12.6

*db re: 0.0002 microbar in ASA type-1 coupler.

large that the effects modified the measured threshold levels substantially. Hence, the influence of sex, ear, and order of test may be disregarded in examining the data at hand with the aim of assessing the relationship between acuity for 1000 cps and acuity for spondees. Technically, the same conclusion applies to the effect of method of test, but common sense argues that the size of the interval used in testing (which differed for pure tones in the two methods of test) should not be ignored completely. The rationale underlying this last statement, plus the basis for other general conclusions, is highlighted by tables IX and X.

Table IX gives mean thresholds, subdivided in terms of method of test and, for the spondee thresholds, the factor of prior knowledge. Table X reports the differences, for the same breakdown of data, between 1000 cps and the spondee threshold. Appropriate combined values are also reported in both tables. The following conclusions seem pertinent and reasonable.

First, as seen in table IX, and as mentioned earlier, the mean thresholds for 1000 cps appear highly equivalent when allowance is made for the fact that the clinical method used a 5 db step as contrasted to the 2 db step employed in the up-and-down method. Thus, it would appear that this threshold can serve as a stable point of reference when the size of the test interval is specified.

Second, the mean thresholds for spondaic words varied appreciably. As already pointed out, the variation with method of testing can be considered random, but the variation due to familiarity with the spondees is systematic. The important point is the fact that the speech threshold is not a point of reference whose stability is comparable to the 1000 cps threshold. Therefore, the establishment of an audiometric norm for speech requires the designation of such additional conditions as: (1) the specific test material on which the norm is based and (2) the audiologic sophistication of the subjects who are the reference group.

Third, as the foregoing conclusions imply and as table X illustrates, the difference between the thresholds for the 1000 cps pure tone and for the W-1 spondees varies substantially. This variation is primarily the result of the instability of the spondee threshold, although the change in the size of the interval used to measure acuity for 1000 cps is thought to have exerted its influence as well. The outstanding point is that the observed differences range from 9.9 to 14.2 db, with the average for all conditions combined being 12.6 db. These differences are all substantially greater than the 6 db value currently designated in the American Standards for Speech Audiometers (2). They are in reasonable agreement with several earlier investigations (3, 4, 5), and smaller than reported by other writers (6, 7).

DISCUSSION

The practical implications of the present study have already been partially stated. These implications are: (1) that a multiplicity of conditions must be specified in order to stabilize the norm for speech audiometry, (2) that the difference between the norms for pure tone audiometry and for speech is a function of the conditions chosen in specifying both but (3) that the difference between the norms for 1000 cps and for speech should be designated as substantially more than 6 db.

The magnitude of the difference which is selected as specifying the standard relation between the threshold for 1000 cps pure tone and threshold for speech must be settled by arbitrary decision of the persons responsible for establishment of standards. The present study can assist these persons only to the degree that it helps to clarify the factors to be considered.

To this end, it is instructive to examine the differences between thresholds exhibited by the 20 subjects used in the preliminary study (see table I) and to compare these results with the findings already reported for the 96 subjects who participated in the main experiment. It probably represents approximately the limiting range to be encountered when subjects involved have "normal" acuity. In other words, the evidence at hand leads us to believe that, when the size of the test interval is constant for both measures, highly sophisticated listeners will detect a 1000 cps pure tone at a sound pressure level about 10 db weaker than the level at which they correctly repeat 50 percent of the W-1 words. This difference may become as great as 17 db in consequence of complete unfamiliarity with the spondee test materials. Since the threshold for 1000 cps is but little affected by audiologic sophistication, the difference may fluctuate over a range of 7-8 db as a result of variation in the threshold for speech.

Assuming that the foregoing analysis is correct, three choices are available in choosing a "standard" difference to be incorporated in a revision of audiometric norms.

If highly sophisticated listeners are selected as the criterion population, a difference of about 10 db must be specified. The practical consequence of such a choice will be that the naive listener (including many a hard-of-hearing person) will yield initial thresholds which are several decibels poorer than his later ones will be, particularly if time is not taken to familiarize him with the test words prior to the initial test.

The reverse situation will exist if the fully naive listener is chosen as the standard. A difference of 15-16 db must now be specified, and any person having appreciable prior experience with the speech material will obtain thresholds which appear better by several decibels than they otherwise would.

The third option is to select a difference of intermediate value (12-13 db). This choice would imply that a moderately sophisticated listener is the criterion, and it would keep the discrepancy in measurement of threshold for other types of listeners small (about 3 db).

This choice (i.e., establishing the difference between the norm for 1000 cps and norm for speech at 12 to 13 db) would seem to be most reasonable. It represents a middle-of-the-road course if one is thinking in terms of spondee words as represented by W-1 recording and also if one is contemplating the array of evidence which studies other than the present one have supplied. Moreover, since the spondaic words have relatively high audibility, even audiologically sophisticated listeners will exhibit a difference between modalities of at least 12-13 db when the speech threshold is determined with other types of material.

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