THE DISCRIMINATION OF PITCH

AND

ITS RELATION TO TRAINING.

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by

William Wallington Norton

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THE DISCRIMINATION OF PITCH AND ITS RELATION TO TRAINING.

The question of the source of musical ability has brought forth such a variety of opinions, that it seems worth while to consider some of the phases of a problem which can be scientifically investigated and may prove of practical value in musical education. Investigators have heretofore tested the upper and lower pitch limits, the threshold of sound perception, discriminative sensibility for differences of intensity and for differences in pitch. As bearing upon the perception of music there have been tests for discrimination of groups of simultaneous tones (chords), of tones heard in succession, for perception of rhythm, and for emotional or affective response. The problem would lead to such questions as: Does pitch discrimination exist in"islands" ? e.g., Can those able to discriminate pitch within the immediate vicinity of A 435 vibrations, do as well in the next octave higher or lower? What part does attention pay in the keenness of discrimination of sounds? If the memory image is involved, what is its nature and importance? Does memory of absolute pitch assist in the fine discrimination? In the present research the work is confined

to discrimination for pitch and intensity, to discover what correlation there may be, to seek an explanation for the great individual differences, and to ascertain the effect of training on pitch discimination.

Survey of the Literature.

Methods.

Some very good work has already been done in discrimination of sounds. C.E.Seashore of Iowa University used a set of tuning forks tuned for increments in height of pitch above international A (435 v.) as follows: 1, 2, 3, 5, 8, 12, 17, 23, 30, v. d.. The standard fork and one differential were sounded in rapid succession, striking them uniformly and holding them close to the ear. Each tone was sounded three seconds with a three second interval. The observer stated whether the second tone was higher or lower than the first. Beginning with the largest interval one trial was given until the region of uncertainty was reached and then ten trials were given. The interval for which eight of the ten answers were correct was consid-

ered the threshold of discriminative sensibility. He tried this test with college students and later with a group of school children from eight to fifteen years of age. For the latter test the forks were rested upon a table instead of being held to the ear. In this way the discrimination is perhaps easier on account of the help that is obtained from differences in timbre which are intensified by the sounding board. *

At Columbia pitch discrimination has been tested with a single wire on the sonometer, a movable bridge being used to vary the pitch.** The monochord was tuned so that F below middle C was given when the bridge was at 75 cm. The directions for making the test were as follows: "Give tone F twice at an interval of about two seconds to the student whose back is turned. Then shift the bridge to about 50 and let the student find the tone. He must be warned against humming the tune and must probably be taught in advance how to use the monochord. Record the position of the bridge and then give the original tone twice and shift the bridge to the place where it was left by the student in his first trial, telling him that it is put back to this place.

* Univ. of Ia. Studies in Psych. II. 55.

** Clark Wissler, Psych. Rev., Mon. Sup. Vol. 3, p.6.

Let him now find the tone and record the position. Ask the student whether he plays a musical instrument, or sings, and record his answers." This test seems to be mainly a test of memory. The interval of time between the standard given and the tone found by the student may vary to such an extent that the judgments may vary accordingly. Unless the student sees the bridge when it is moved to about 50 he will not know in which direction to move the bridge in finding the standard without sounding the string when the bridge is at 50 and determining in which direction to move. He may not know on which side of the bridge the tone is to be given. All these difficulties may be provided for in the clause "taught in advance how to use the monochord".

Hughes used two wires on the sonometer, thus partially obviating the question of tone memory,* but at the same time it has the disadvantage of the two strings stretching unequally, while the stretching of only one string leaves the interval the same. The tone was established by a stroke of a hammer on the string. Hughes insists that in all tests for pitch discrimination the subject must reproduce the tone, and suggests, "This may be done by the voice: but in the absence of any practical

* Psych. Rev. 1902, IX, 603.

phonautograph an accurate test of pitch perception cannot be obtained in this way." Even if a phonautograph were available, the method is faulty because keen pitch discrimination is no guarantee that the tone heard can be reproduced. In my tests, I found at least one observer who could not "carry a tune" that showed a keener pitch discrimination than an acceptable glee club singer. No general statement can be made, of course, from only one case, but it goes to show that a keen discrimination does not always mean the ability to "carry a tune". This would seem to indicate that an untrained musical memory, or lack of control of the vocal chords might account for poor musical expression. For class purposes Hughes used forks which were tuned by adding wax. The method of tuning seems faulty as the wax is not sufficiently permanent.

Gilbert* at Yale, used an adjustable pitch pipe graded to produce tones 1/32 of a tone apart. He sounded "a" (435) and then a tone 1/32 of a tone higher; the child answering "same" or "different". The next interval was 2/32 higher, and so on until the child had several times declared the tones to be different. The same method is followed taking those tones

* Stud. from Yale Psych.Lab. 1892093, p .80

lower than "a". The number of thirty-seconds of difference that were perceived was noted in the two cases; the average gave the result of a single experiment. B.R.Andrews criticizes this method*, for in the two series of Gilbert he has to determine the limen at two distinct points on the scale, and then average the unrelated values. Andrews suggests that by commencing the second series at the upper value "a" + n/32 and taking a descending series, the values in both ascending and descending series are found for the same liminal band on the scale, which he regards as a much more accurate method. The use of the pitch pipe has the disadvantage that all wind instruments have, especially when the mouth is used, that they can be varied in pitch so easily by the slightest variation in the force of the air. The harder one blows the higher the tone, and the lighter the pressure the lower the tone.

Alderton ** suggests that the most satisfactory method of establishing the tone with the forks is to strike it upon a thick rubber pad. He has used this successfully in his musical work. Whipple at Cornell *** in 1901 commenced some tests in pitch with the Appon tonometer with tones ranging from 512 to

* Am. Jour. of Psych. 1905, XVI, 300

**Arch. of Otol. Vol. XXIII. p 171.

***Am. Jour. of Psych. 1901-02 -03

1024 vib. He tested both above and below his standard with the same interval. He also used the Stern Tone-variator in tests for pitch of chords.

Angell and Harwood worked with the Appun tonometer with a range of an octave and with the difference of four vibrations between the stops. These experiments were coupled with a series of experiments with distraction. While four vibrations may be near the average minimal interval for discrimination, yet the fact that so many have a finer discrimination would suggest the advantage of using a smaller increment.

A.N.Andrews, in a study of "Sources of Error in Functional Tests of Hearing", * gives many suggestions in method. He regards tuning forks and Galton's whistle as practically the only reliable instruments for making functional examinations. Weighted forks are suggested as having the advantage of being free from overtones, and those with the least metallic ring when struck with a pencil prove the most satisfactory. Alderton quotes Emerson as saying that forks after use do not vibrate as long as when new, but the pitch remains unchanged. After use they also have a tendency to give with more emphasis the

* Laryng. 1902. XII. p 249.

overtones.*

Baldwin, Cattell, Jastrow and Sanford, comprising a committee**on tests of the American Psychological Association, offered a number of suggestions. Baldwin and Sanford recommended the selection of "a match from a set of forks, giving a fixed number of vibrations per second more or less than a standard of 500 vibrations such as 497, 497.5, 498, 498.5, etc, 500, 500.5, 501, 501.5, etc." Cattell and Jastrow suggested the adjustment of "one monochord or pipe to another, the tones not to be sounded simultaneously." No further details as to the method of procedure were made. Allowing the one tested to manipulate the instruments has some advantages, and yet it furnishes opportunity for variation of the method in each individual case. The results could be computed by the method of average error, which has some advantages over that of right and wrong cases, yet the method would not be available for a group test.

Rough and rapid work can be done with a piano in discovering extremely poor pitch discrimination for intervals of a semi-tone or more. The tests can be tried in various octaves to determine whether differences of pitch are equally well perceived

* Arch. of Otol. XXIII. p 173

**Psych. Rev. 1897. IV 134

with low and high tones.

Stumpf* recommends his fusion experiments as a test of musical ability. This involves tests with chords, as do also the tests of Max Meyer of the University of Missouri.**

Results and Conclusions.

Seashore found that in a group of fifty-eight adults, nineteen women and twenty-nine men, the best observer recognized a difference of two vibrations, while five were unable to perceive a difference of thirty vibrations. More recently he has found several who discriminate one vibration. Women were superior to the men. No marked relation was found between a keen sense of hearing and discriminative sensibility for pitch. In his tests with children, as given by Miss Northey, they found that many children who had a high grade of tone sensibility had no musical education. The reverse was also found to be true. A child of eight in the group of 166, ranging from 6 to 13 years, never failed to perceive a difference of two vibrations, while only a small percent of musically trained adults could reach that limit. Of three cases who had a musical education, two failed

* Stumpf Tonpsychologie. 1883 I/ 315

** Psych. Bulletin V. 1908, No.2 p 42

to lower their thresholds for discrimination at all after twenty periods of practice on twenty successive days; one made some improvement but had a relapse in the trials that were continued after the twentieth day. Of the two who had no musical education, one, a girl aged twelve, could not perceive an interval of 30 v.d. at the beginning, but gradually improved up to a threshold of five vibrations in the twentieth trial. (It seems possible then in some cases to have great improvement with practice). The other, a University student, remained at the same threshold, 12 v.d., during the twenty periods of practice. Seashore * believes that the average individual variations, independent of age or sex, must be accounted for chiefly by structural differences in the sense organs. "It is probable that the organ of Corti reaches its maximum efficiency at the age of about ten, and that it then begins to deteriorate, especially if it is not called into systematic activity. This would be analogous to the fact that the range of perceptible pitch early reaches its maximum extent in children and then gradually narrows down, so that adults do not perceive as high or as low pitch as children." The fact that he found no functional relation between general mental

* Seashore, op. cit. 62

ability and discriminative sensibility for pitch, he offers as the strongest evidence in favor of the theory that the discrimination sensibility for pitch depends principally upon the natural structure of the end organ and is subject only to small variation with education. "There is a natural limit to discriminative sensibility for pitch which may be reached with little or no practice."* If this conclusion is correct it is important as indicating that little need be allowed for the practice element in a pitch test. The following scale for the interpretation of results is suggested by Seashore on a basis of tests of 110 adults and 380 children: (a) a child whose limen is two vibrations or less may become a musician; (b) three to eight vibrations should have a plain musical education, and singing in school should be obligatory; (c) nine to seventeen vibrations, singing in school optional, and a plain musical education should be given if special inclination for music is shown; (d) eighteen vibrations or above should have nothing to do with music.** B.R.Andrews feels that this scale is not only arbitrary, but its applications would result in injustice. He thinks musical capacity cannot be judged from tests on a single factor such as pitch

* Seashore , op. cit.

** Educ. Rev., XXII, 76

discrimination. "Moreover pitch discrimination depends in good part upon practice: a person who could just discriminate a difference of 20/54 of a tone might, with practice, reduce this to 10.54.* A still better one is cited above from Seashoré's own results. Andrews further emphasizes that no child should be considered hopelessly unmusical until given an opportunity for musical training.

"The fact that the subjects discriminated an interval of one-third of a tone not much better than one of one-ninth of a tone may, perhaps, be taken to indicate that the growth in accuracy is a matter of cerebral more than of aural development. Another indication in this direction is that the older children in a class who are more likely to be 'left backs' did rather worse than the rest of the class, as a rule. Two or three of the teachers remarked on the apparent connection between general intellectual inferiority and the inferiority according to his tests."**

Whipple at Cornell believes that the auditory image figures largely in the discrimination. "If the particular pitch which is recognized, happens (when the variable is sounded) to be actually in process of central excitation in the form of an auditory image of the standard, the recognition is, in all

* Am. J. of Psych. 1905, XVI, 306

** Hughes op. cit. 609

probability, aided by this fact. If we attribute musical ability at bottom to a specific, transmissable nervous tendency, we do not preclude the possibility of greatly modifying this tendency by post-natal training, whether favorably or unfavorably."*
Angell and Harwood quote Wolf's work on tone memory as corroborating their experience that, in the case of discriminative judgments, the attention usually becomes more and more concentrated and the discriminative powers increase with practice.

Pillsbury says,** "Much of what passes for extreme acuteness of some special sense is nothing more than the result of a special training of the attention to greater efficiency in one particular line. There is a popular belief, for example, that the eye of the savage is much keener than the eye of civilized man. It is true that he will notice a foot-print where the civilized man will not be able to see the slightest disturbance of the ground. He will also detect the approach of an animal by the ear when another would not be conscious of any sound, and so on. Instances of his peculiar perfection of sense could be drawn from each class of sensation. It is not

* Am. J. of Psych. 1903. XIV 304

**Pillsbury "Attention" p 40, 41, 42

that the organs are more perfect, however. It is merely that all their training during their lifetime has been concentrated upon recognizing and interpreting the particular objects and differences which have a meaning for the chase, and in adult life no element of the perception that can have the least bearing upon this point can escape him. For the sailor every mark upon the horizon is correctly interpreted, and every small object is seen, because there are images in mind ready to be called out by any impression that is likely to appear there. The passenger by his side sees the same impressions, but there is nothing in the mind to favor the entrance of the important phases as opposed to the unimportant, and he will notice one as readily as the other. That it is the special training rather than the keenness of sense that makes the difference can best be shown by repeating the test with some material for which there has been no special preparation. If you ask the savage to describe the characters upon a printed page he will not see as much as a boy of six; or compare the sailor's perception of a microscopic preparation with the trained biologist's, and you

would find him placed at a greater relative disadvantage than was the passenger at sea compared with himself."

"The ear of the musician is probably not more delicate than the ear of the untrained man in the recognition of differences of pitch or of intensity, it is only that his training has prepared him to notice combinations and shades that will escape other men. The extraordinary acuteness of sense developed by tea tasters and others who rely upon one sense almost exclusively for complicated determinations is to be traced similarly to mental rather than to sensory training. The effect is central rather than peripheral— mental, not physical."

Tests Given at Minnesota.

The tests at the University of Minnesota were given to six different groups of students largely composed of sophomores. The groups averaged about 50 students. A total number of 276 complete records were made, 100 in the Spring of 1909 and 176 in the Fall of the same year. Three tests were given; two for discrimination of pitch, with tuning forks and with a sonometer, and one for discrimination of differences in intensity with a sound pendulum. The tests were given in two parts with an interval of two days between the trials. The double fatigue order was used as follows: forks, two complete tests, sonometer, two complete tests, for the first day; the second day we commenced with the sound pendulum, giving three complete tests, then one test with sonometer and completing the tests with one with forks. The observer also filled out a questionnaire, based on one prepared by Seashore, covering their musical experience such as musical training, musical environment, musical expression and enjoyment of music. (See Appendix A)

Apparatus.

In the fork test we used a set of tuning forks tuned for increments in pitch below international A (435 v.) as follows: $\frac{1}{2}$, 1, 2, 3, 5, 8, 12, 17, 23, 30 v.d. It may be noticed that forks are below instead of above international A, thus varying from the set used by Seashore in 1899. A resonater of wood constructed to reinforce the tones was used to make them of sufficient intensity for the entire class to hear. Small forks were used of uniform size and shape, 11.5 cm. long. We found that the nickel plating was liable to peel off thus introducing a possible change of the tone. An annealed fork would, therefore, be better. The forks were tuned and tested at Seashore's laboratory by means of the tonoscope* thus assuring their accuracy. A thick rubber pad, 4 x 6 x 1, was used on which to strike the forks. The rubber was rather soft, such as is used for a steam gasket, to avoid the metallic ring which all hard substances seem to emphasize. It was difficult with this method to obtain great enough intensity, and with a group test it would probably be better to use the method of striking the fork later described in the training experiment.

* Ia. Studies in Psych. 1902, p 18-28

The sonometer test was given with one wire one meter long with a movable bridge to vary the tone. The wire was a heavy No.15 piano string. The bridge was arranged with an edge of ivory at the top in which was a groove for the string. Braces were placed at the ends of the bridge projecting down over the sides of the sonometer so that the bridge might be slid along easily without variation from side to side. The groove in the ivory was just high enough for the string to rest with a slight pressure. The possibility of overtones can be lessened by resting the finger just beyond the bridge. Our method has the possible disadvantage of stretching the string but it was found that the variation for an hour was never more than a vibration, and the fact that we were using only one wire leaves the relative pitches virtually the same. For the standard, the bridge was set at 750 mm. from one end. A good violin bow, well rosined, was used to establish the tone being drawn across the wire about six sevenths the distance from the bridge, thereby avoiding the exaggeration of some of the overtones. As the experimenter plays the violin the bowing could be kept quite uniform. The

intervals given corresponded to the forks.

For the intensity test a swinging pendulum with a ball at one end was allowed to fall and strike a firm ebony block just as the pendulum reached its perpendicular position. For the standard it was allowed to fall through an arc of 90 degrees, the distance being measured from the center of the ball. Zero degree is at the center of the ball when perpendicular.* The reliability of the falling pendulum has not been established, Pillsbury even suggesting that it may vary 50 percent. It is probably as accurate, however, as any single device. A screen was placed before all apparatus to avoid suggestion through vision.

Method of the Tests.

In order to insure that the groups understood the purpose and method of the problem, full instructions were given before each of the three tests, each point being illustrated. (See Appendix B.)

First test: A series of forks were sounded in sets of twos, commencing with the two forks which are the greatest in-

* See further description; Judd lab. equip. for Psych. Exp. p 133.

terval apart and passing through smaller intervals until we reached identical forks, and then reversing and going back through the series to the forks of greater difference. The descending series closed with two As and without notice passed over to the ascending series which commenced with a repetition of the same two As. To the observer a series consisted of twenty-two judgments including the descending and ascending series. This plan was repeated three times thus giving six judgments on each interval. Two trials were given before each judgment was recorded. The word "one" , "two", "three", etc, on to "twenty-two" to complete the series, was given before the first tone of each set was sounded, and the word "repeat" before the second trial. In every case the judgment was noted down regarding the second fork in relation to the first fork by "S" for same, "L" for lower and "H" for higher. This form of judgment is better than the one used by Gilbert of "like" and "different", for it is recognized that at the limen it is much easier to judge whether two tones are alike or different in pitch, than to state specifically whether the one

tone is lower or higher in pitch than the other. One case is a judgment of a simple difference and the other is one of qualitative difference of direction.* In some of our results the simple difference was perceived but the direction incorrectly determined. The latter form of judgment is to be desired because it is that sort of discrimination used in music, both in listening and in performing-- we are not interested in a simple difference. Any distraction of attention was noted down by a circle around the initial and the record was discarded. Such distraction was so infrequent that it did not affect their record. The students were in a regular recitation room, those finding it difficult to hear distinctly occupied front seats. All were requested to face the apparatus directly. Whether the second tone was higher or lower depended entirely upon chance, throughout the test, so that each judgment was given independently of what went before. The chance order was arranged so as to have the standard given first, as many times as the varied forks. A caution was given against humming. It was impressed upon the students that our purpose was to secure independent results, and for that reason

* Stumpf op. cit. I, 313

they should take great care not to copy or prompt each other, or to make any comparison during the test.

The intensity of the tone from each fork was kept as uniform as possible, for in any judgment of pitch, a difference in intensity may be mistaken for a difference in pitch. Stumpf found cases where the judgments of pitch differences were always made in terms of intensity. The louder tone was always judged to be the higher.* Each fork was sounded for two seconds with less than a second interval between the forks, thus eliminating the question of auditory memory. In order to do this the forks were struck simultaneously, the intensity of the one taken off being about the same at the time of removal from the resonator as the second one at the time of placing it upon the resonator. Since auditory memory and imagery are a necessity, in vocal music particularly, a reasonable interval of time between the two sounds would make the tests similar to practical conditions as found in music. The sonometer test was given with an interval of time between the two tones of perhaps two seconds, to make the adjustment of the bridge. Care must be exercised that the forks are of the same

* Stumpf, op. cit. I, 315

temperature as this may be a source of error.

Second test: The method used with the sonometer was similar to that used with the forks except for the interval of two seconds between the two tones. This was kept as uniform as possible. Stern has shown that certainty of judgment is affected by the length of the time interval between the two tones.* Whipple thinks four or five seconds is maximal although shorter periods may be used.** The same precaution as to humming, copying, etc, were taken in this test as with the forks. The bow was drawn across the wire with a firm uniform pressure so as to avoid as far as possible differences of intensity and exaggeration of overtones. A different chance order than that used with the forks was followed in giving these tones. The intervals corresponding to the forks, using the bridge at 750 mm. from one end as the standard (435 v.), were located on the sonometer by comparing directly with the forks until beats were eliminated. They were found to be as follows:

435 v. - 30 v. equals 805 mm.; 435 v. - 23 v. equals 791 mm.;
435 v. - 17 v. equals 780 mm.; 435 v. - 12 v. equals 771 mm.;
435 v. - 8 v. equals 765 mm.; 435 v. - 5 v. equals 760 mm.;

* Zeitsch. f. Psych. u. Phys., XXI, 1899, 377-379

** Am. J. Psych. XIV. p 301

435 v. - 3 v. equals 756 mm.; 435 v. - 2 v. equals 754 mm.;

435 v. - 1 v. equals 752 mm.; 435 v. - ½ v. equals 751 mm.

The intervals may be calculated mathematically by the formula:

$$\frac{\text{Distance X}}{\text{Distance A}} \qquad \frac{\text{Vibrations a}}{\text{Vibrations x}}$$

Where vibrations a equals 435 and distance A equals 750, we have the following determinations for placing the bridge at the points for the various vibration differences:

.5 v.d.	750.8 mm.	8.0 v.d.	764.1 mm.
1.0 v.d.	751.7 "	12.0 v.d.	771.0 "
2.0 v.d.	753.4 "	17.0 v.d.	780.5 "
3.0 v.d.	755.2 "	23.0 v.d.	791.8 "
5.0 v.d.	758.7 "	30.0 v.d.	805.5 "

In determining these points mathematically no allowance can be made, of course, for any variation in the string so that probably the method of eliminating beats by comparison with the forks is satisfactory. However, it may be noted that the two tables correspond quite closely. The extreme difference , being .3 mm., is less than one-half a vibration and could not be discriminated by more than about two people in a hundred of those tested.

The bridge was quickly moved to these various points, care being taken to dampen with the sleeve of the coat the first tone given before the bridge was moved.

Third test: A series of sounds of different intensities were given in twos, commencing with the two of the greatest difference and approaching those of the same intensity. The series were continued as with the tests for pitch discrimination, from the

same intensity back to those of greater difference. The intensity differences were measured by the following differences in the arcs in which the pendulum fell; 60, 46, 34, 24, 16, 10, 6, 4, 2, 1, closing the descending series with two of the standard 90 degrees and starting the ascending series with the same, continuing through the series to the 60 degree difference. These increments were arbitrarily chosen it being understood, of course, that the differences in physical intensities do not bear the same relation to each other as the degrees; i.e., a 60 degree fall does not give just twice as intense a sound wave as a 30 degree fall. There was no particular reason for arranging them in relative physical intensities to correspond with the pitch relations since we did not know whether the judgments were similar or not and the arbitrary increments were chosen simply with a view to giving a good test. Two trials were given before each judgment was recorded. The interval of time between the sounds was kept as uniformly as possible at two seconds. A third chance order was used in giving the intensities. The judgments of the second sound in relation to the first sound were recorded by "S"

for same, "L" for less intense, and "M" for more intense. Each preliminary direction was illustrated as in the two preceding tests.

The question of fatigue and affective tone as shown in the interest of the students in the test has been entirely neglected although it may have its influences in the results. The results show, however, what might be expected under the average condition of attention found in a large class.

On the following pages a sample record and the key used for checking the records is given.

A Sample Record.

Date 9/16 '09 Hour 9:30 A.M. Observer 292 Year in College Junior

	Tuning Forks				Sonometer				Intensity				
	A	B	C		F	G	H		K	L	M		
1	L	H	L		H	L	H		M	L	M		
2	L	L	H		L	L	L		M	M	L		
3	H	H	H		H	H	L		L	L	L	34	
4	L	L	L		L	L	H		~~S~~	M	~~M~~		24
5	H	L	L		L	H	L		~~S~~	M	~~S~~		
6	H	H	H		~~H~~	H	L	5	L	L	~~M~~	10	
7	H	L	H		~~S~~	H	H	3	~~S~~	~~S~~	L		
8	L	H	L	2 2 2	~~S~~	~~S~~	H		~~M~~	~~M~~	M		
9	~~S~~	~~S~~	~~S~~		~~S~~	~~S~~	H	1	~~M~~	~~M~~	~~M~~		
10	~~S~~	~~M~~	~~S~~		~~S~~	~~S~~	~~S~~		~~S~~	M	~~S~~		
11	S	S	~~M~~		S	S	S		~~L~~	S	S		
12	S	S	~~L~~		S	S	S		S	~~M~~	~~M~~		
13	~~S~~	~~S~~	H		~~S~~	~~S~~	~~S~~		L	~~S~~	L		
14	~~M~~	~~S~~	~~S~~		~~S~~	~~S~~	H	1	~~M~~	~~M~~	~~L~~		
15	H	H	H	2	H	~~S~~	L		~~S~~	~~M~~	L		
16	~~S~~	L	H		L	L	L	3	~~S~~	~~S~~	L		
17	L	L	~~M~~	5	~~S~~	L	L		M	~~L~~	~~S~~	10	
18	L	H	L	8	~~L~~	L	L		M	L	M	16	16
19	H	L	H		L	H	H	12	L	M	L		
20	L	H	H		H	L	L		M	L	L		
21	H	L	L		L	H	H		L	M	M		
22	H	H	L		H	H	H		L	L	M		

The median of the six judgments with the forks is 2 which means 1.5 v. d. for the record. The median variation from the median record is 0.

The median of the six judgments with the sonometer is 3 which means 2.5 v. d. for the record. The median variation from the median record is 1.63.

The median of the six judgments with the intensity is 16 which means 13 degree difference for the record. The median variation from the median record is 6.

The Key Used in Scoring the Records.

	With Tuning Forks			With Sonometer			With Intensity		
	A	B	C	F	G	H	K	L	M
1	L	H	L	H	L	H	M	L	M
2	L	L	H	L	L	L	M	M	L
3	H	H	H	H	H	L	L	L	L
4	L	L	L	L	L	H	M	M	M
5	H	L	L	L	H	L	L	M	M
6	H	H	H	H	H	L	L	L	L
7	H	L	H	L	H	H	L	M	L
8	L	H	L	H	L	H	M	L	M
9	H	H	H	H	H	H	L	L	L
10	L	L	L	L	L	L	M	M	M
11	S	S	S	S	S	S	S	S	S
12	S	S	S	S	S	S	S	S	S
13	H	L	H	L	H	H	L	M	L
14	L	H	L	H	L	H	M	L	M
15	H	H	H	H	H	L	L	L	L
16	L	L	H	L	L	L	M	M	L
17	L	L	L	L	L	L	M	M	M
18	L	H	L	H	L	L	M	L	M
19	H	L	H	L	H	H	L	M	L
20	L	H	H	H	L	L	M	L	L
21	H	L	L	L	H	H	L	M	M
22	H	H	L	H	H	H	L	L	M

The above key shows the chance order in which the standard and the variable were given in each test.

The Method for Scoring Results.

In scoring the results under this method of absolute change with knowledge in a descending and ascending series, the best of the continuously successive correct judgments was determined in each of the six series and the median of those six records was used as the measurement for the discrimination of that individual in that test. The median is nearer the true average than an average would be with so few trials since one case at either extreme would decidedly affect the average, but not the median. And in case 30 v.d. was not recognized that record would have to be excluded in calculating an average. To illustrate the plan of scoring, if the record for an individual in one series showed all correct judgments up to eight vibrations, since there were no tests between eight and five vibrations the record should mean on the average that he would get $\frac{8+5}{2}$ or 6.5 vibrations correct. His record for that series was scored as 6.5. The median for the six series was taken as his total record for the test. The meaning of the records which showed the last continuously correct judgment at each of the rates of vibration

used is given in the following tables:

Table I.		Table II.	
30 v.d. correct means	26.5	60 Deg. correct means	33.
23 v.d. correct means	20.	46 Deg. correct means	40.
17 v.d. " "	14.5	34 " " "	29.
12 v.d. " "	10.	24 " " "	20.
8 v.d. " "	6.5	16 " " "	13.
5 v.d. " "	4.	10 " " "	8.
3 v.d. " "	2.5	6 " " "	5.
2 v.d. " "	1.5	4 " " "	3.
1 v.d. " "	.75	2 " " "	1.5
½ v.d. " "	.25	1 " " "	.5
0 v.d. " "	0.0	0 " " "	0.0

The records for both men and women were grouped together, there being only 41 men and 235 women and so very little opportunity for comparison of any sex differences.

This method of scoring may have done an injustice to some who had two or three judgments correct after the first mistake. The difficulties of scoring, however, would probably be as serious with other methods.

Individual Variations.

The variation of different individuals in pitch discrimination is quite pronounded. With the sonometer they range from a discrimination of .25 of a vibration to more than 30 vibrations. The average of the median records was 5.8 vibrations and the average variation 4.7 vibrations while the mode was 2.5 vibrations. With the forks the individuals range from a discrimination of .75 vibrations to more than 30 vibrations. There were eleven observers unable to tell a difference of 30 vibrations. The average of the median records of the individuals was 6 vibrations and the average variation 4.2 vibrations, while the mode was 3.5 vibrations. The distribution of the cases showed a skewed curve as two-thirds of the cases fall between 0 and 4.5 vibrations. A rather peculiar fact was that there were only two who could not discriminate at least 30 vibrations with either the forks or the sonometer.

In the intensity test the variations ranged from more than 60 degrees to 3 degrees. The average of the medians of the 276 cases was 13.3 degrees and the average variation 3.9 degrees.

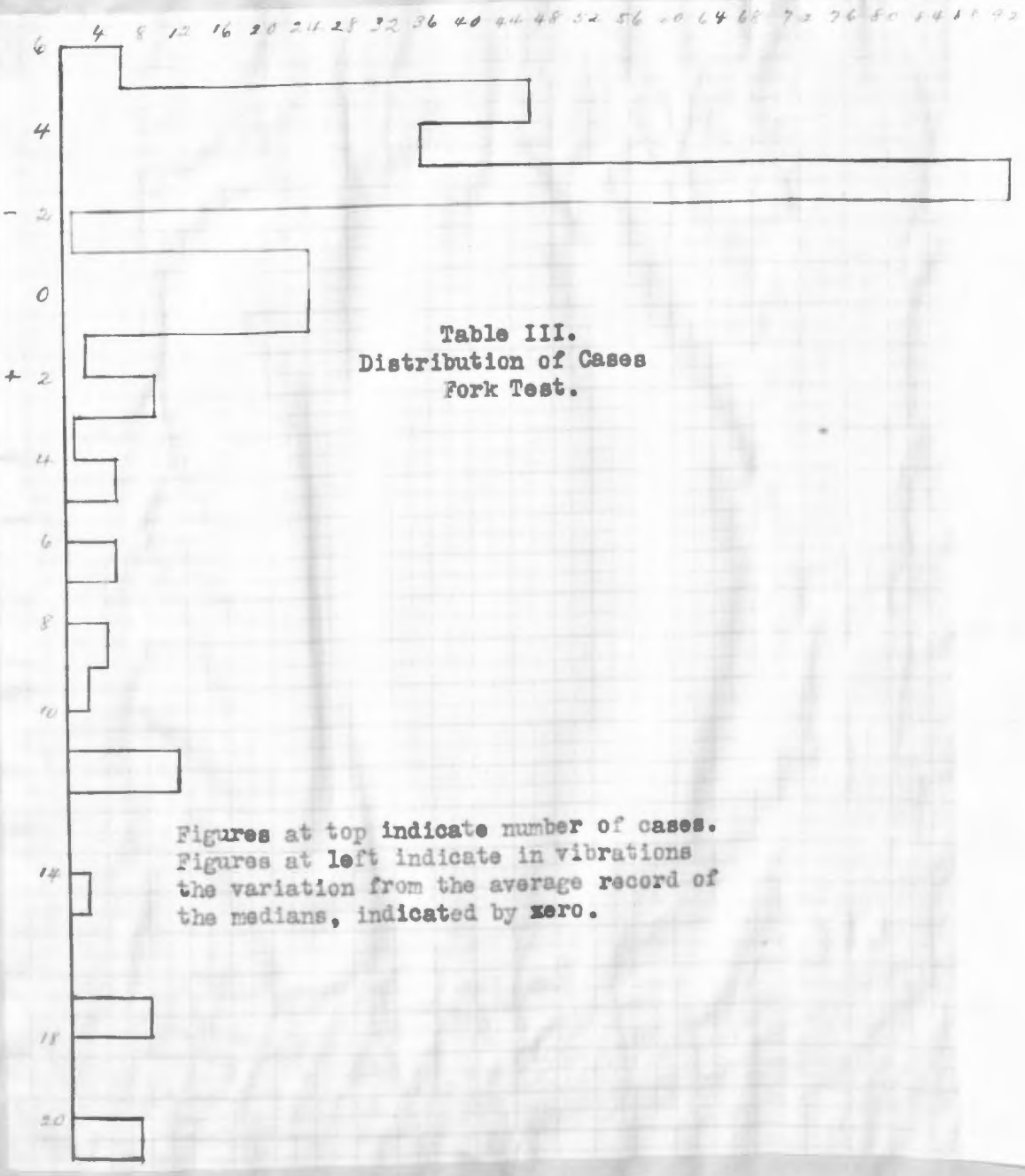


Table III.
Distribution of Cases
Fork Test.

Figures at top indicate number of cases.
Figures at left indicate in vibrations
the variation from the average record of
the medians, indicated by zero.

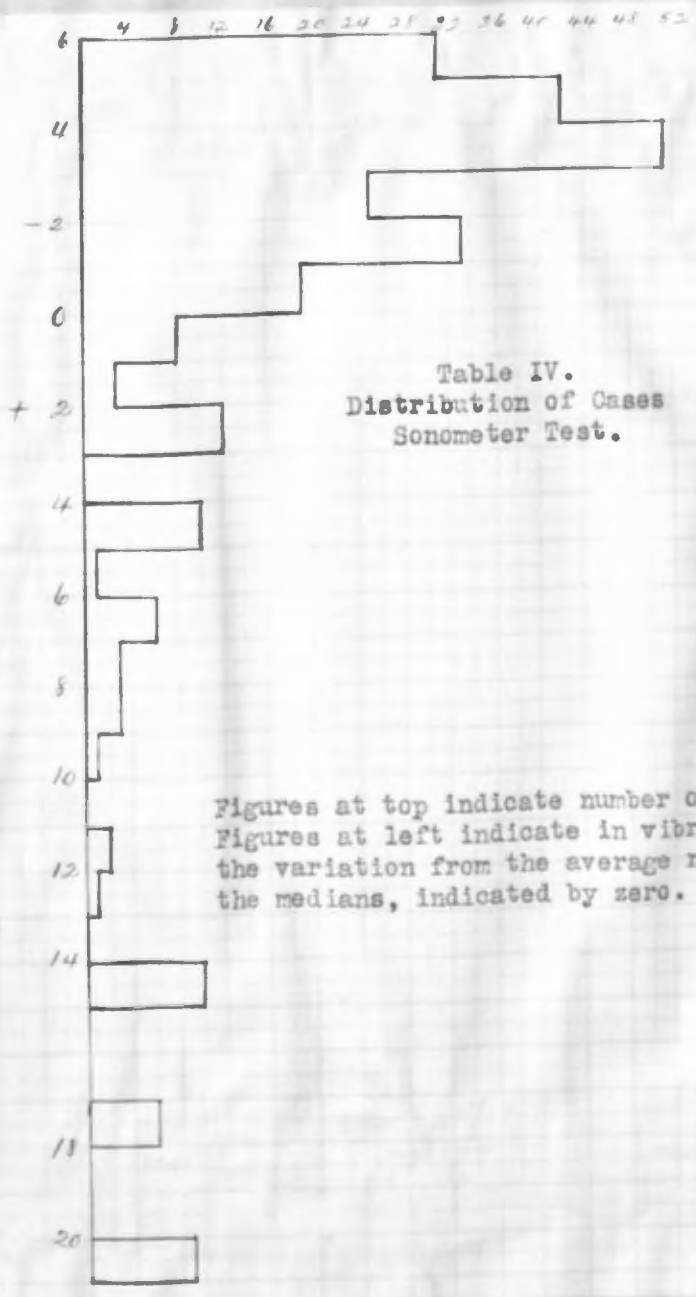


Table IV.
Distribution of Cases
Sonometer Test.

Figures at top indicate number of cases.
Figures at left indicate in vibrations the variation from the average record of the medians, indicated by zero.

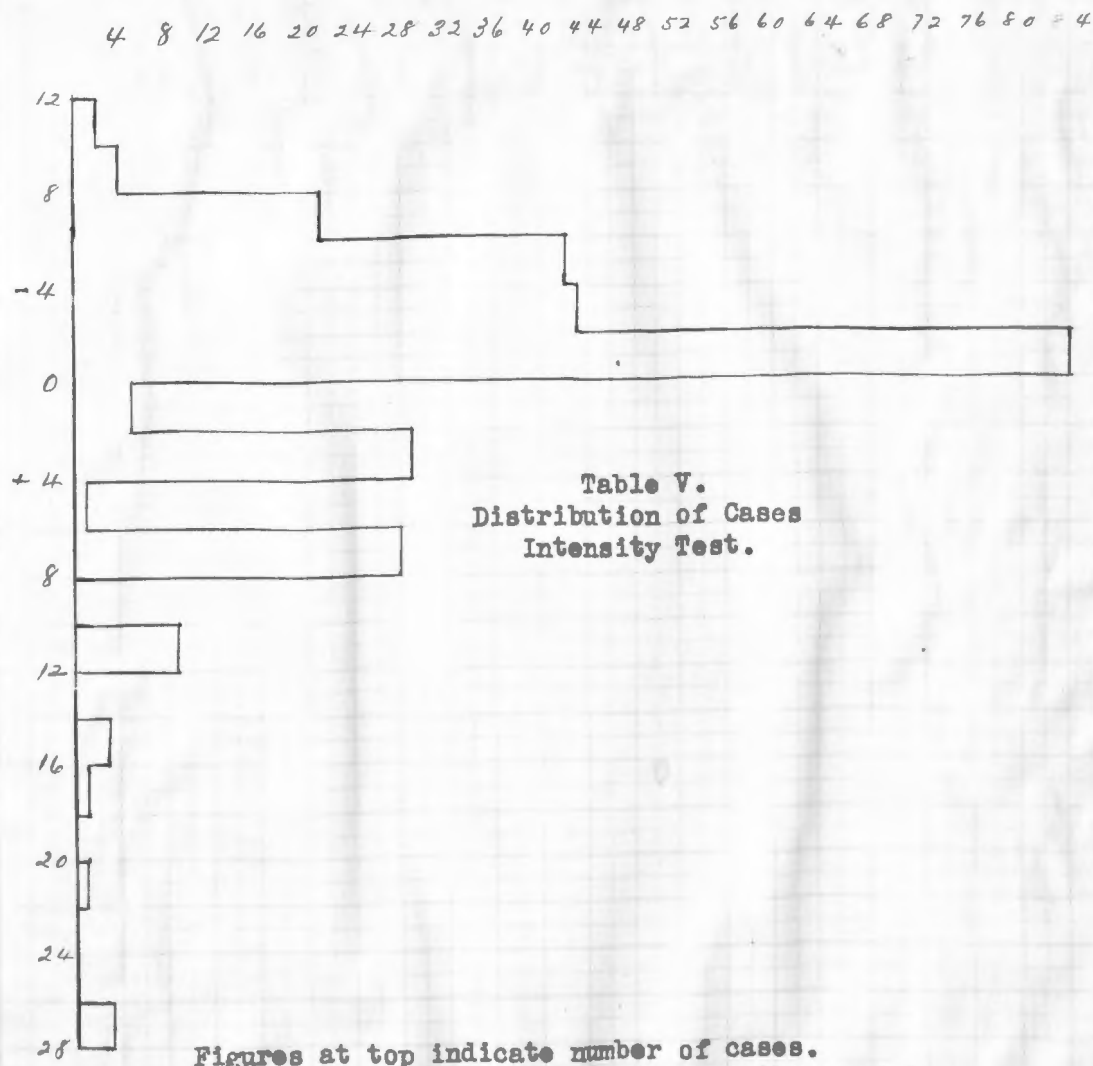


Table V.
Distribution of Cases
Intensity Test.

Figures at top indicate number of cases.
Figures at left indicate in degrees the variation from the average record of the medians, indicated by zero.

The large variation in the distribution of the cases in the fork test (Table III) as shown between 2 and 4 vibrations better than the average is rather significant and seems difficult to explain. If the method of scoring would group the cases at this point, the same condition would prevail for the sonometer. Upon careful examination of the fork three vibrations from the standard it was found to have quite a decided overtone which may have been confusing at that point thereby bunching the records toward the average. This may account in part for the fewer number of low records as compared with the sonometer. The overtone may have developed from the peeling of the plating which suggests a serious fault in this fork test. Annealed forks would undoubtedly be much better.

Comparison of the Two Extremes in their Musical Experience.

The 20 parties unable to discriminate 30 v. in one of the two pitch tests have the following records in the other tests and musical experience as furnished by the questionnaire. The tables are made out according to the four headings in the questionnaire: I. Musical training, II. Musical environment, III. Musical expression, IV. Enjoyment of music. (See Appendix A)

Table VI.

No. 19. 17.25 v.d. forks. 30+ v.d. sonometer. 34.5 Intensity.

I. Meagre public school training. No vocal lessons. Four years piano lessons.

II. Piano little used. No trained voices in family. Hears occasional concerts and operas.

III. Cannot sing. Plays Mendelssohn and Leybach. Cannot reproduce tune "in the head".

IV. Enjoys music in general. Musical knowledge has helped her to appreciate classical music better. Wants to see performer in order to enjoy music.

No. 26. 30 + v.d. forks. 17.25 v.d. sonometer. 16.5 Intensity.

I. One year public school training once a week. No vocal lessons. No instrumental lessons.

II. No instruments in home. No singers. Hears light opera and friends play occasionally.

III. Sings none. Plays none. Cannot reproduce "tune in head".

IV. Enjoys opera, chorus and vocal solo, symphony and band. Has not noticed difference in not seeing performer.

No. 38. 30+v.d. forks. 17.25 v.d. sonometer. 53. Intensity.

I. No musical training except twenty piano lessons.

II. Violin, cornet and organ in home. Two singers. Brother and sister have studied music.

III. By ear sings choruses of sacred music. Plays "Narcissus" and "Flower Song". Can reproduce "tune in head".

IV. Enjoys all vocal music. Instrumental he prefers symphony. No effect of not seeing performer.

No. 39. 30+ v.d. forks. 23.25 v.d. sonometer. 53. Intensity.

I. Regular public school training. No vocal or instrumental lessons.

II. Brother plays piano by ear, has taken no lessons. No voices in the family. Has heard few concerts.

III. Can't sing or play. Can recognize a tune heard very often.

IV. Has no particular preferences. Enjoys music by marching and beating time. Must see performer to enjoy it.

No. 58. 30+ v.d.forks. 12.25 v.d. sonometer. 13. Intensity.

I. Very little training in public schools. No vocal or instrumental lessons.

II. Organ and piano in home. Limited opportunities for hearing music.

III. Sings one or two selections. Does not play. Difficult to reproduce tune "in head".

IV. Enjoys quartette, chorus and popular music. Prefers instrumental solos. Enjoys music through its rythm.

No. 75. 17.25 v.d. forks. 30+ v.d. sonometer. 16.5 Intensity.

I. Some training in high school. No vocal or instrumental lessons.

II. Piano used for rag time and hymns. No trained voices. St. Paul Symphony Orchestra heard occasionally.

III. Has no preferences vocal or instrumental. Whistles some favorite selections.

IV. Enjoys quartette and popular music. Enjoys marching. Must see performer to enjoy music.

No. 93. 14.5 v.d. forks. 30+ v.d. sonometer. 10.5 Intensity.

I. Little training in high school. Piano lessons a few years.

II. Piano, mandolin and cornet in home used but slightly. Never heard much music until coming to college.

III. Cannot sing or play. Cannot reproduce a tune "in the head".

IV. Enjoys "any kind of soft, sweet music." Enjoys the rythm in dancing. More pleasing to see performer.

No.104. 23.25 v.d. forks. 30+ v.d. sonometer. 16.5 Intensity.

No.111. 26.5 v.d. forks. 30+ v.d. sonometer. 16.5 Intensity.

I. Little training in public schools. Very few instrumental lessons.

II. Piano in home. Family likes to sing.

III. Plays a little by note. Reproduces tune fairly easily.

IV. Enjoys quartette and popular music. Prefers to see performer.

No. 148.20 v.d. forks 30+ v.d. sonometer. 20. Intensity.

I. Slight in grades. Piano lessons 1½ yrs.

II. Piano and violin in home used by other members of family.

III. Never appeared in public. Can reproduce tune "in head" fairly well.

IV. Solos, quartette and band. Prefers not to see performers.

No.165 23.25 v.d. forks. 30+ v.d. sonometer. 20. Intensity.

I. Only in H.S. 1½ yrs. piano lessons.

II. Piano in home. No opportunity to hear music till two years ago.

III. Sang in choir. Cannot reproduce tune "in head".

IV. Enjoys chorus and band. Must see performer.

No.171. 30+ v.d. forks. 30+ v.d. sonometer. 20 Intensity.

I. One year in public school. Voice lessons ten months. Piano lessons one year.

II. Piano, flute, trombone, in home. Brother and sister musical.

III. Sings popular songs by note. Plays two-steps and marches. Can reproduce a tune "in the head".

IV. Enjoys catchy solos and band. Likes dancing. Prefers to see performer.

No. 184. 30+ v.d. forks. 23.25 v.d. sonometer. 20 Intensity.

I. Took 60 piano lessons.

II. Piano in home used by children for practice.

III. Play piano little by note. Is able to reproduce tune "in head".

IV. Enjoys solo, chorus, opera, symphony and band. Likes music as well not seeing as seeing performer.

No. 196. 30+ v.d. forks. 18.25 v.d. sonometer. 16.5 Intensity.

I. Six voice lessons. Piano lessons four years.

II. Piano in home used for practice.

III. Plays some. Reproduces tune "in head" fairly well.

IV. Enjoys all vocal music, band. Prefers to see performer.

No. 208. 30+ v.d. forks. 20.5 v.d. sonometer. 13 Intensity.

I. No public school music. No voice lessons. Ten piano lessons.

II. Piano in home which sister used.

III. Sings "old favorites". Not able to reproduce tune easily.

IV. Enjoys band, quartette. Gets more out of music when performer is not seen.

No. 220. 30+ v.d. forks. 7. v.d. sonometer. 13 Intensity.

I. Few songs in school. Four years piano lessons, but no interest.

II. Piano in home used some.

III. Sings a few fraternity songs by ear.

IV. Enjoys good opera, symphony and band. Only a decided

rythm has any interest. Necessary to see performer to enjoy the music.

No. 246. 12.25 v.d. forks. 30+ v.d. sonometer. 8 Intensity.
I. Public school training. 20 irregular piano lessons as child.
II. Piano and organ used considerably. One trained voice.
III. Plays a little by note. Can reproduce "tune in head".
IV. Fond of all music. Enjoys dancing. Prefers to see performer.

No. 252. 26.5 v.d. forks. 30+ v.d. sonometer. 24.5 Intensity.
I. Three months instrumental lessons.
II. Piano, violin, organ in home.
III. Does not sing. Plays few waltzes by note. Cannot reproduce "tune in head".
IV. Enjoys pipe organ especially, band, solos.

No. 255. 30+ v.d. forks. 30+ v.d. sonometer. 13. Intensity.
I. Public school training in Mpls.
II. Seldom hears any music but church music.
III. Sings very little by ear. Can "think" a tune.
IV. Enjoys vocal quartette and band.

No. 282. 30+ v.d. forks. 26.5 v.d. sonometer. 20. Intensity.
I. No training.
II. Piano and organ in home. Two singers but no interest.
III. Believes can sometimes reproduce a "tune in head".
IV. Enjoys opera, band, popular.

Of the six who had the poorest discrimination with the intensities, the following table will give their discrimination in the other tests and their musical experience as given in the questionnaire.

Table VII.

No. 38. 53 Intensity. 30+ v.d. forks. 23.25 v.d. sonometer.
See Table VI.

No. 39. 53 Intensity. 30+ v.d. forks. 17.25 v.d. sonometer.
See Table VI.

No. 69. 40 Intensity. 12.25 v.d. forks. 20.5 v.d. sonometer.
I. One year,one hour per week in high school. No vocal lessons. Twelve organ lessons.
II. Organ in home. No singers in family. Heard first good music in 1908.
III. Does not sing . nor play now. Cannot reproduce "tune in her head".
IV. Enjoys quartette and symphony. Enjoys rythm in music.

No.121. 40 Intensity. 17.25 v.d. forks. 20 v.d. sonometer.
I. Slight training in grades. Instrumental lessons three years.
II. Piano in home. No musical encouragement at home.
III. Sings and plays a little by note. Never appeared in public. Can reproduce "tune in head."
IV. Enjoys vocal solo, piano and violin. Enjoys music through its rythm. Prefers to see performer.

No. 156. 41. Intensity. 4. v.d. forks. 5.25 v.d. sonometer.
I. Training thru public schools. Instrumental lessons three months.
II. Piano played by mother. Father sings. Exceptional opportunities.

III. Sings and plays by note. Can reproduce "tune in head." Has sung in public.
IV. Enjoys all good music. Prefers to see performer.

No.169. 60+ Intensity. 7. v.d. forks. 2.5 v.d. sonometer.
I. Training thru grades. Piano lessons five years.
II. Piano played by two sisters.
III. Can reproduce "tune in head".
IV. Enjoys solo, quartette and band. Prefers to see only a singer.

With the forks there were twenty-seven who had a discrimination of 1.5 v.d. or less. The following table gives the musical experience, and the discrimination in the other tests of the four who had the best discrimination with the forks:

Table VIII.

No.136. .75 v.d. forks .25 v.d. sonometer 3. Intensity.
I. Public school training. Violin lessons.
II. Has heard symphony concerts and the finest soloists for many years.
III. Sings some of the classics. Sang in choir two years. Can reproduce any tune "in her head".
IV. All good music appeals. Keen appreciation of rythm. Prefers not to see performer. Enjoys Wagner and Beethoven.

No.163. .75 v.d. forks. 5. v.d. sonometer 6.5 Intensity.
I. Complete public school training. Violin lessons seven years.
II. Piano, clarinet and violin in home. Piano and violin used most. Hears all Symphony concerts, etc.
III. Plays many violin solos. Has played in orchestra. Can reproduce "tune in head" very easily.
IV. Enjoys all good music. Prefers seeing performer.

No.230. .75 v.d. forks 2. v.d sonometer. 13. Intensity.

I. Scales, sight reading, elements of harmony in public schools. Three months voice lessons. Piano lessons eight years.

II. Piano, guitar, mandolin in home. Hears best concerts in Twin Cities.

III. Sings popular airs. Plays much in public. Can reproduce tune.

IV. Enjoys all the best music and some popular. Enjoys the music itself better when she does not see the performer.

No.276. .75 v.d. forks. 1.5 v.d. sonometer. 8. Intensity.

I. Practice in vocal training by singing in male quartette.

II. Cornets in home. Three members of family play cornets.

III. Sings some by note and plays in band. Can reproduce a "tune in head".

IV. Enjoys quartette, chorus and opera, symphony and band. Rythm does not stand out as strong feature in enjoyment. Prefers not to see performer.

With the sonometer there were sixty-eight who had a discrimination of 1.5 v.d. or better. Seventeen of them were able to discriminate .5 v.d. or better. Of the seven who had the best discrimination with the sonometer the following table will give their discrimination with the other tests and their musical experience as furnished in the questionnaire;

Table IX.

No.113. 0. v.d. sonometer .88 v.d. forks. 24.5 Intensity

I. Training in grades and H.S. 24 piano lessons. 24 violin lessons.

II. Piano, cello, clarinet, mandolin and two violins in home.

III. Plays some by note. Played in orchestra for one year. Can reproduce "tune in head" very well.

IV. Enjoys bass solos, male quartette, opera and symphony. Prefers to see performer.

No.136. .25 v.d. sonometer. .75 v.d. forks. 3. Intensity.
See Table VIII.

No.138. .13 v.d. sonometer. 3.25 v.d. forks. 20. Intensity.
I. Through grades. Piano lessons two years.
II. Piano used almost contantly. One trained voice in family. Hears the Symphony Orchestra frequently.
III. Sings hymns and opera selections. Plays Schumann, Verdi,etc. Has sung solos in public. Can reproduce "tune in head" easily.
IV. Enjoys all good music. Inspired and thrilled by it. Enjoys seeing performer when their presence is not eccentric and thus distracting from music.

No.143. .13 v.d. sonometer, 2. v.d. forks. 14. intensity.
I. Reading and writing music in public schools. Voice lessons one year. Piano lessons one year. Violin lessons three years.
II. Piano and violin used most of the time. Mandolin not used much.
III. Has sung first soprano in choir. Played first violin in orchestra. Played in piano duets. Can sometimes hear tune that is hard to reproduce.
IV. Solos, opera, symphony and all classical music appeal most. Prefers to see performer because it seems easier to hear.

No.256. .25 v.d. sonometer 1.5 v.d. forks. 21. intensity.
I. Public school training. One year voice study at Oberlin. Four years piano lessons.
II. Piano not used much. Violin played by younger sister. Hears much good music.
III. Has sung and played in public. Reproduces "tune in head" easily.
IV. Enjoys music immensely, such as solos, opera, symphony and chamber music. Prefers classical. Prefers to see the performer.

No.265. .25 v.d. sonometer. 4. v.d. forks. 9. intensity.

I. Singing with class. Three years piano lessons.

II. Piano used every day. Hears Symphony Orchestra frequently.

III. Enjoys singing "Hail,Minnesota". Plays by ear and note. Likes Verdi very much. Can reproduce "tune in head" easily.

IV. Enjoys chorus, opera, symphony, and prefers classical but for recreation enjoys popular occasionally. Sembrich is better not seen. Schumann-Heink adds charm to the music by her presence.

No.291. .25 v.d. sonometer. 1.5 v.d. forks. 8. intensity.

I. Learned to read by note and the elements of music. Violin lessons one year.

II. Piano, mandolin, guitar and violin used moderately. Hears much good music.

III. Plays and sings both by ear and by note. Played in H.S. orchestra three years and sang in choir one year.

IV. Enjoys all good music when well rendered. Prefers not to see performer.

Of the five who had the best discrimination with intensities, the following table will give their discrimination with the other tests and their musical experience as given in the questionnaire;

Table X.

No. 80. 3. Intensity. 2.75 v.d. forks. 1.63 v.d. sonometer.

I. Piano lessons several years.

II. Piano in home played by mother and sister, clarinet by brother. Entire family sing in part songs. Hears very much of the best music.

III. Sings and plays by note in public. Can reproduce "tune in head"easily.

IV. Enjoys classical music. Prefers not to see performer.

No. 86. 5 Intensity. 4. v.d. forks. .5 v.d. sonometer.
I. "Picked up" playing of piano.
II. Piano in home. Brother a trained singer. Hears Symphony concerts and other good music.
III. Sings by ear and by note. Has sung in choruses rendering oratorios etc. Can reproduce tune "in head."
IV. Enjoys all music. Musical knowledge helped in discriminating the differences. Enjoys music as much when not seeing the performer.

No. 28. 5 Intensity 3.25 v.d. forks 2.5 v.d. sonometer.
I. Training thru grades and High School.
II. Piano in home played by all members of family. Brother a trained singer.
III. Sings and plays piano and pipe organ by note. Hears much good music. Can reproduce "tune in head".
IV. Enjoys all good music, Not seeing performer "intensifies effect of music."

No. 136 3 Intensity .75 v.d. forks .25 v.d. sonometer
See Tables VIII and IX.

No. 268 5 Intensity 2.5 v.d. forks 2.5 v.d. sonometer
I. Training in chorus in High School.
Between ages 10 and 12 took 104 piano lessons.
II. Piano, cornet, alto. Plays on piano and cornet, Much singing in home. Hears much good music.
III. Sings and plays by note. Has played in orchestra. Can reproduce "tune in head."
IV. Enjoys quartette and symphony. Musical knowledge helps to enjoy best music. Depends on performer whether cares to see.

If it is just to base judgments on so few cases, it would seem from the indications in the five tables above, that training had played a very important part in the ability to discriminate the

sounds. Almost without exception the cases which had the keener discrimination, had had vocal training thru the grades and had taken private lessons of some sort for varying periods. All had one or more instruments in their homes in constant use. The majority enjoyed the music as well when the performer was not seen and some enjoyed it more. Among those with the poorer discrimination, all had a meagre public school training and only a few had taken either vocal or instrumental lessons. The instrument studied was the piano or some other instrument which needs little discrimination of pitch less than a half a tone. Several had instruments in their homes but in every case they were used but slightly. A number of them say they cannot sing. It is interesting to note that so many of them enjoy music thru its rhythm. It may be that they recognize some tunes thru the rhythm rather than the pitch relations. Such cases are known. Some had not noticed the difference in their enjoyment of music as affected by not seeing the performer, but for the majority it was necessary for them to see the performer to enjoy the music at all. It rather suggests that the performance, enjoyed largely thru vision, appeals because of its acrobatic nature.

It is rather interesting that those showing the poorest discrimination in intensities should have similar musical experience with two exceptions, to those poorest in pitch discrimination.

The Variation of the Individuals in the Sonometer Test.

In order to ascertain the variation of each individual from his median record the median variation from that median record was calculated. The average variation from the average of the records for the entire group has already been given but as a further check upon the reliability of the records an average of these individual median variations was determined and found to be 1.68 vibrations with 254 cases. The extremes ranged from 0 to 14.5 vibrations and only a few of the latter variation. This may be given as an indication of what might be expected in the fork test also.

Correlation.

Do those having a keen discrimination in one function have a tendency to have a keen discrimination in the other functions? The correlation tables have been arranged in arrays according to the variation from the average record. Thorndike's graphic method of finding the median ratio* has been used as it shows the ratios of each array, which is essential when the distribution is not normal. The median ratio also is less disturbed by extreme cases than the Pearson coefficient. The ratio between the two functions has to be reduced to equivalence in variability when the mean variation of each function is different as in these tests. The coefficients of (median ratios) after thus allowing for the difference of variability are .94 for the forks and sonometer; .47 for the forks and intensity; and .65 for the sonometer and intensity. The Pearson coefficient would be the most probable ratio for each array only if the distribution in each characteristic was according to the normal curve of probability. In each characteristic the curve is skewed so the Pearson coefficient seems inadequate. The Pearson coefficients however, have been calculated and are .75 for forks and sonometer;

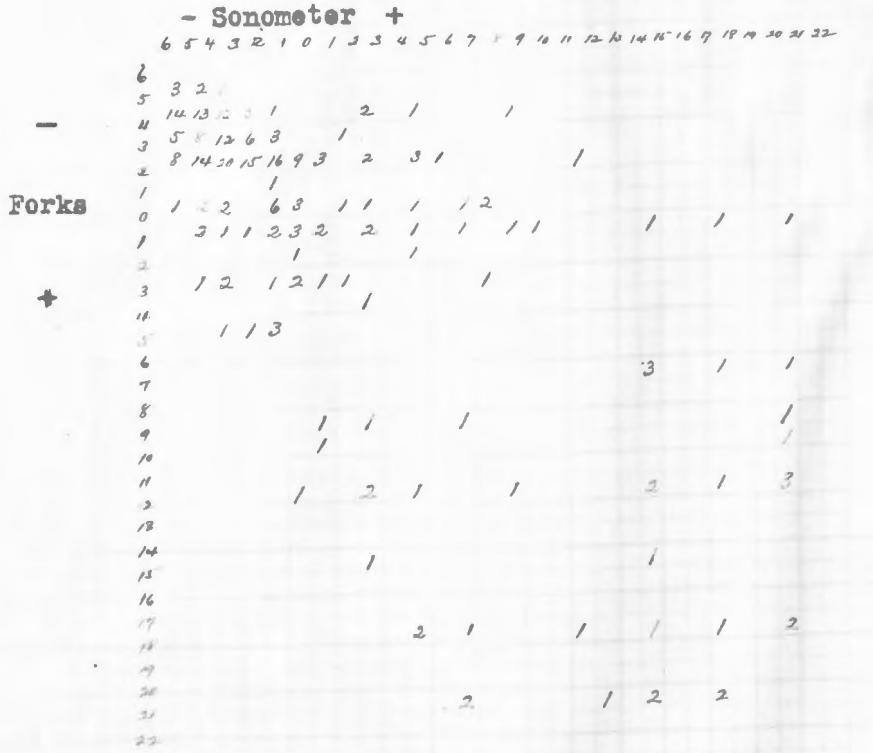
* Empirical Studies in the Theory of Measurement. Arch. Psych. No. 3

.30 for the forks and intensity; and .39 for the sonometer and intensity. The modal ratios or the ratios at which there are the greatest number of cases are 1.0 for forks and sonometer; .65 for forks and intensity; and .65 for sonometer and intensity. The graphic correlations are given in tables XI, XII and XIII.

Tables XIV and XV show the distribution and correlation by quartiles for the group between the records for forks and previous musical experience, and between the records for the sonometer and previous musical experience. The grouping for musical experience was dependent entirely upon the judgment of the writer and was based upon the information furnished in the questionnaire previously mentioned. Care was taken not to see the record while classifying them according to musical experience. At best this correlation is a rough estimate but serves to show the tendency for those in the best quartile in one to be in the best quartile of the other, also the tendency for those in the poorest quartile of one to be in the corresponding quartile in the other.

Table XI.

The Correlation and Distribution of Cases Fork and Sonometer Tests.

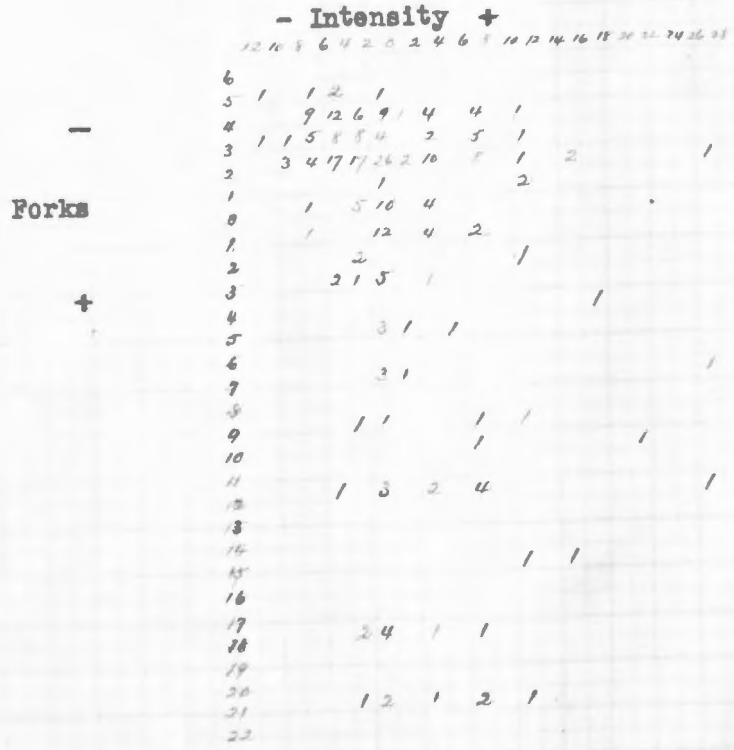


Median ratio .94 Pearson coefficient .75 Modal ratio 1.00

Figures at the top indicate in vibrations the variation from the average, indicated by zero. Figures at the side indicate the same for the forks. The other figures indicate the number of cases at that point.

Table XII.

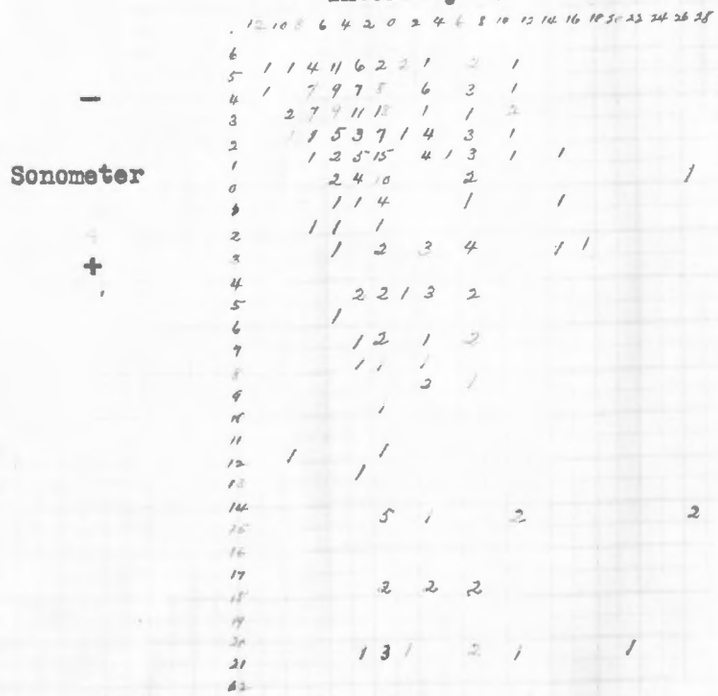
The Correlation and Distribution of Cases Forks and Intensity Tests.



Median ratio .47 Pearson coefficient .30 Modal ratio

The figures at the top indicate in degrees the variation from the average, indicated by zero. The figures at the left indicate in vibrations the variation from that average. The other figures indicate the number of cases at that point.

Table XIII.
The Correlation and Distribution of Cases Sonometer and Intensity Tests.



Median ratio .65 Pearson coefficient .39 Modal ratio .65

The figures at the top show in degrees the variation from the average indicated by zero. The figures at the left indicate in vibrations the variation from that average. The other figures indicate the number of cases at that point.

Table XIV.

Musical Experience.

Forks

	IV	III	II	I
IV	59% (43)	28% (20)	12% (9)	1% (1)
III	29% (21)	33% (24)	33% (24)	6% (4)
II	8% (6)	24% (17)	29% (21)	40% (29)
I	4% (3)	16% (12)	26% (19)	53% (39)

Table XV.

Musical Experience.

Sonometer

	IV	III	II	I
IV	62% (45)	28% (20)	10% (8)	(0)
III	26% (19)	32% (23)	36% (27)	6% (4)
II	8% (6)	19% (14)	34% (25)	38% (28)
I	4% (3)	22% (16)	19% (13)	56% (41)

The numbers in parenthesis indicate the actual number of cases.
The Roman numerals indicate the quartiles.

It will be noticed in table XIV that nearly 53% of those in quartile I of the musical experience are in quartile I for the records with the forks. (Quartile I is the best quartile) Again that 59% of those in quartile IV of musical experience are in quartile IV of records for forks. 292 cases have been used in these last correlations, those whose discrimination was above 30 vibrations have been included.

In studying table XV it will be seen that 56% of those in quartile I of musical experience are in quartile I of record for sonometer, and that 62% of those in quartile IV of one are in the same quartile of the other. The two middle quartiles may be compared in the same manner.

Comparison of Methods for One and Two Judgments of each Interval.

At the time of giving the test the question arose as to the actual advantage of two trials over one trial in determining the judgment for each interval. Because of the uncertainty of manipulation, variations in intensity and possible overtones it was assumed that a judgment based on two trials would be better. To try out the method, the test with the forks was given to 59 college

students on two different days in which they recorded the judgments for each trial and in case of a difference in the two judgments, underlined the one of which they were more sure. On the first day the average discrimination where only the first judgment was scored, was 7.05 vibrations. For the more certain of two judgments it was 7.09 vibrations. On the second day the averages were 5.58 vibrations and 5.37 vibrations respectively. The better of two judgments affected the median of 19 cases for the better and 19 cases for the worse. The difference in the average for the two methods is so slight that this check experiment suggests that the two trials gave no better judgment especially after the manipulation of the apparatus had been perfected. However, the one trial method has the advantage of saving time in which more could be given.

Comparison of Methods with Forks and Sonometer as a Test for Pitch Discrimination.

From the tables showing the distribution, the sonometer test shows greater regularity. Of those whose discrimination was under 1.5 v.d. there were 27 cases with the forks and 68 cases with the sonometer which seems to indicate that the discrimination

was easier with the sonometer. This might be expected, since we have a pure tone with the forks and a complex tone with the sonometer, the overtones serving as a secondary means of discrimination. The difference in the mean variation of the two test is not significant enough to favor either. The mean variation for the forks was 4.2 v. and for the sonometer 4.7 v. One serious fault in the method with the forks was the manner in establishing the tones by striking them on the rubber pad. This created intensity differences that may account for the poorer records made with the forks. The use of a rod covered with rubber tubing and suspended from the left hand against which the forks were struck, was found to be much more satisfactory as used in the training experiment. From the data furnished in these tests it would seem that, provided the operator is practiced in bowing a string the sonometer is slightly the better test for pitch discrimination, although it is possible that the other method of striking the forks might have avoided the irregularity in the fork records. The necessity of setting the bridge of the sonometer for each test and the consequent interval between tones are disadvantages with the sonometer test.

The Training Experiment.

Six of those who showed poorest pitch discrimination in the above tests were selected to try the effect of training upon their ability to discriminate.

The apparatus was the same used with the other tests with the exception that the tones of the forks were established by striking them against a vertical bar suspended from the left hand. The bar was covered with rubber tubing 3/16 of an inch thick.

Method.

For half an hour, five days a week, for two weeks the test as given in class was repeated with the following differences:- the tones of the forks were established as described above. One trial was given for each interval. After each judgment was recorded, the correct judgment was given for comparison with the one noted down, a line being drawn thru the record in case of error. The parties were thoroughly instructed before the test began. (See Appendix C) There was no practice between the tests. Some of the subjects took the training at 4 P. M. and some at 1:30 P. M.

By checking the record each day the subjects kept track of their progress thus largely overcoming the effect of monotony in the same practice each day. This also, instilled a spirit of competition, both to excell one's own previous record and that of the others. Introspections were noted down and the subject's own interpretation for a poor record. Any fatigued condition or other factor thought to influence the record was also noted.

The Easter vacation of one week intervened and then the following method was used for two weeks, it being found that the subjects learned that the 11th and 12th judgments were always "S" by the original method and as a result they were not really making judgments at this point in the series. It was also thought that greater practice effect might be obtained if the intervals more easily discriminated were longer repeated. Commencing with the interval of 30 v.d., ten trials were given (the order of the forks being determined by chance as previously). The correct judgment was given and checked after each trial with the one noted down. As far as possible when three or more mistakes were made in the ten judgments the interval was repeated, otherwise the next smaller interval was taken. Since in some cases the test was being given to three

Subjects at the same time there was a variation in the method due to the difference in the discrimination of the three subjects. It undoubtedly would have been better to train them separately.

Method of Scoring Results.

The records according to the first method were scored as in the original tests. The records with the last method were scored in percentage of right judgments and reduced to the record for 75% correct judgments by the table given by Fullerton and Cattell. * As the record for the day we took the median for the records of the last correct series and all those following. While there are some valid objections to the roughness of this method yet it seems quite satisfactory to get the general effect of the practice. On the last day the original test was given and the record scored as for the larger group.

Results.

In the check experiment made to compare one and two trials for the judgment of each interval a rather significant fact as showing the practice effect of one day, was the difference in the records of the two days. In both instances (one and two trials)

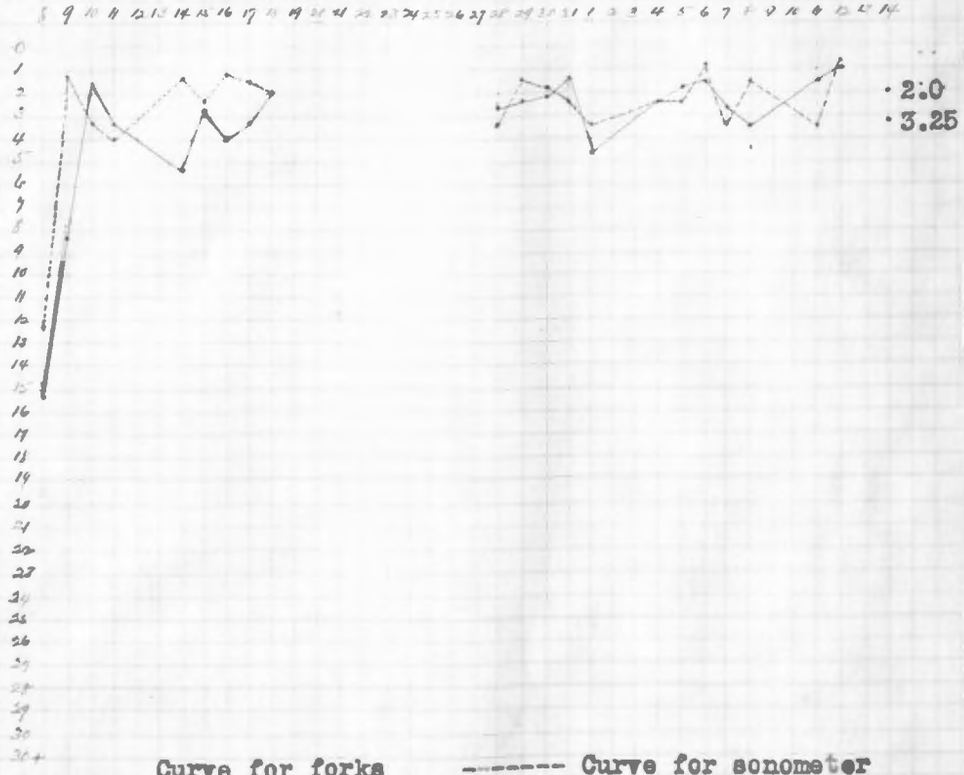
the records were better the second day, 7.05 v. as compared with 5.58 v. and 7.09 v. as compared with 5.37 v. Two days intervened between the tests.

In examining the practice curves given on the following pages we must take into consideration various factors which influence the learning process especially the physical condition of the subject. Frequently we hear the subject say "What was easy for me yesterday is hard today" or "This seems to be my off day" or "It seems as if I had to 'warm up' before I can do good work". Interest in the work seems to be another important factor. "One cannot escape a dead level in uninteresting work, and after the enthusiasm that novelty stirs has spent itself the interest is dulled and effort slackens".* "Fatigue from any cause not only brings a lowering of the day's score but the entire process of learning is probably hindered." ** These various factors and their influence will be pointed out in discussing the individual curves.

Practice Curve for forks and sonometer.

No. 184

March Vacation April



_____ Curve for forks ------- Curve for sonometer

Figures at left indicate vibration differences. April 14 "My mind was wandering or I would have made a better record."

Original record with the class 30+ v.d. forks 23.25 v.d. sonometer

First day's record 15.25 v.d. forks 12.25 v.d. sonometer

Last day's record 3.25 v.d. " 2.00 v.d. "

The curves show 21 periods of practice.

Table XVI

No.184 Forks

	No. of Judgments.	Med. Var.	Med. Record
Mar. 8	2	11.25	15.25
9	4	1.75	8.25
10	4	.9	1.63
11	4	1.63	3.25
14	4	1.25	5.25
15	4	1.25	2.75
16	4	.0	4.
17	4	1.25	3.25
18	4	1.25	2.
	Series of 10 Judgments		
28	2	1.2	2.6
29	2	.15	2.4
30	3	.3	2.1
31	4	.6	1.4
Apr. 1	4	1.0	4.6
4	4	.0	2.3
5	2	.5	1.9
6	2	.5	1.5
7	2	1.2	2.6
8	2	1.	3.3
11	5	.1	1.5
12	3	.0	1.
	No. of Judgments		
14	6	.75	3.25

Table XVI a

Sonometer

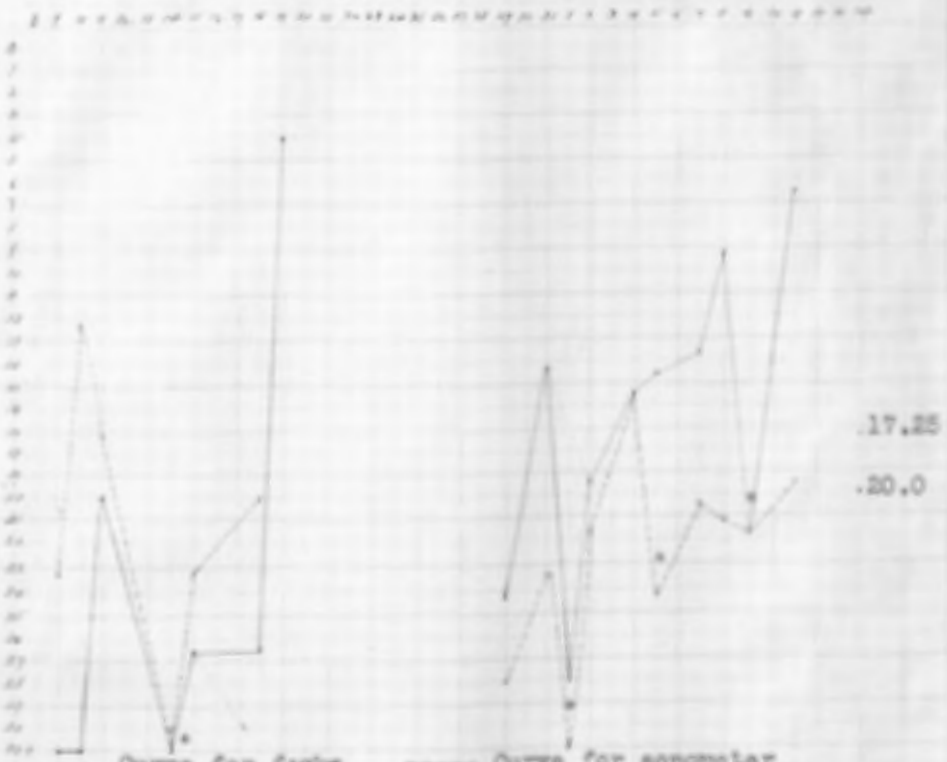
No. 184

	No. of Judgments	Med. Var.	Med. Record
Mar. 8	2	2.25	12.25
9	4	.63	1.13
10	4	.75	3.25
11	4	2.00	4
14	4	1.12	1.38
15	4	1.88	2.13
16	4	.38	1.13
17	4	.0	1.5
18	4	.5	2.
	Series of 10 Judgments		
28	1		3.4
29	1	.0	1.4
30	4	.45	1.9
31	1	.0	2.3
Apr. 3	3	.8	3.4
4	1	.0	2.3
5	1	.0	2.3
6	2	.4	.9
7	2	.0	3.4
8	3	.1	1.5
11	3	1.1	3.4
12	1	.0	.8
	No. of Judgments		
14	6	.87	2.00

Practice Curve for Forks and Sonometer.

No. 171

March Vacation April



____ Curve for forks ----- Curve for sonometer

Figures at left indicate vibration differences. * Judgments in terms of intensity. "Louder ones sound higher." Headache April 1.

Original class record	30+	v.d. forks	30+	v.d. sonometer
First day's record	30+	v.d. forks	23.25	v.d. "
Last day's record	20.0	v.d. "	17.25	v.d. "

Curves show 16 periods of practice.

Intensity was a constant factor of disturbance.

Table XVII

Forks.

No.171

	No. of Judgments	Med. Var.	Med. Record
Mar. 9	2		30+
10	4		30+
11	4		20
14	4		30+
15	4		26.5
18	4		26.5
19	4	1.25	4.
	Series of 10 Judgments		
29	4	7.9	24.2
31	4	4.4	14.3
Apr. 1	5	19.1	28.
2	4	4.1	19.4
4	5	5.1	15.3
5	6	4.8	14.6
7	5	2.1	13.6
8	4	4.	9.2
9	6	7.9	21.8
11	6	1.9	6.5
	No. of Judgments		
14	6	3.25	20.00

Table XVII a

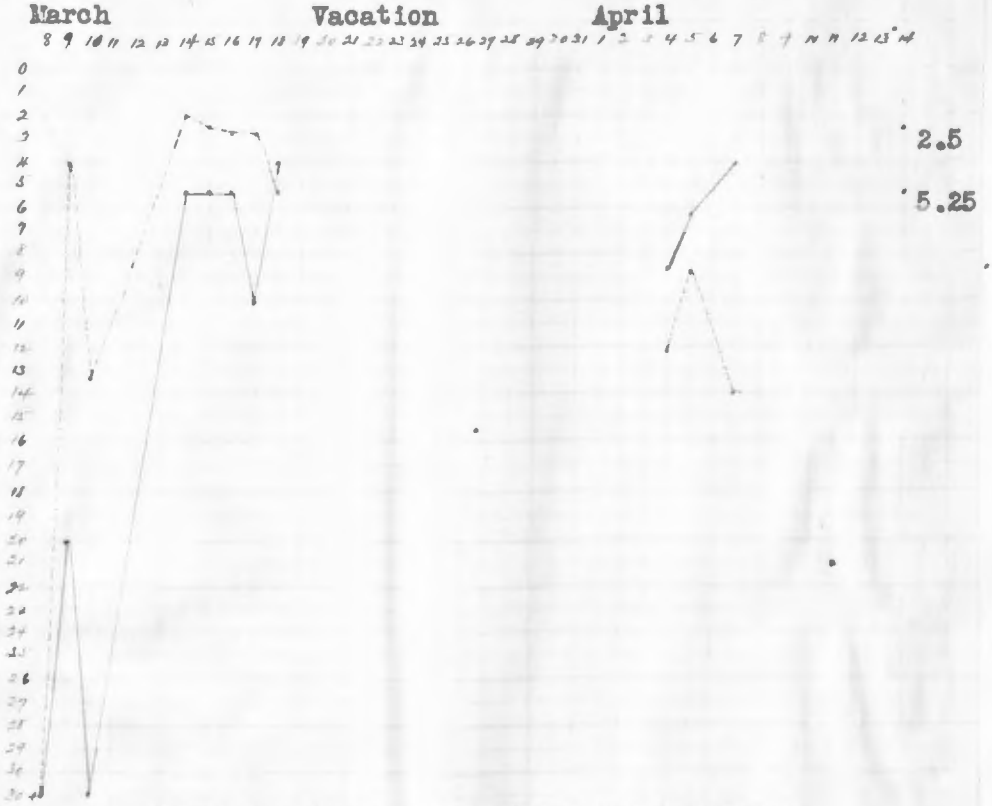
Sonometer

No. 171

	No. of Judgments	Med. Var.	Med. Record
Mar. 9	2	3.25	23.25
10	4	4.	12.25
11	4	5.	17.25
14	4		30+
15	4	6.	23.25
18	4	2.7	20
	Series of 10 Judgments		
29	3	16.7	28.
31	4	6.4	23.4
Apr. 1	3	1.5	43.2
2	5	6.2	21.8
4	5	8.7	15.3
5	4	4.8	24.2
7	3	2.	20.4
8	4	1.7	21.1
9	5	9.7	21.8
11	4	4.8	19.4
	No. of Judgments		
14	6	6.0	17.25

No. 58

Practice Curve for forks and sonometer.



_____ Curve for forks ----- Curve for sonometer

Figures at left indicate vibration differences. Mar. 10 " I had two hours hard work preceding the test."

Original class record	30+ v.d. forks	12.25 v.d. sonometer
First day's record	30+ v.d. "	30+ v.d. "
Last day's record	2.5 v.d. "	5.25 v.d. "

The curves show only 11 periods of practice and given rather irregularly.

Table XVIII
Forks

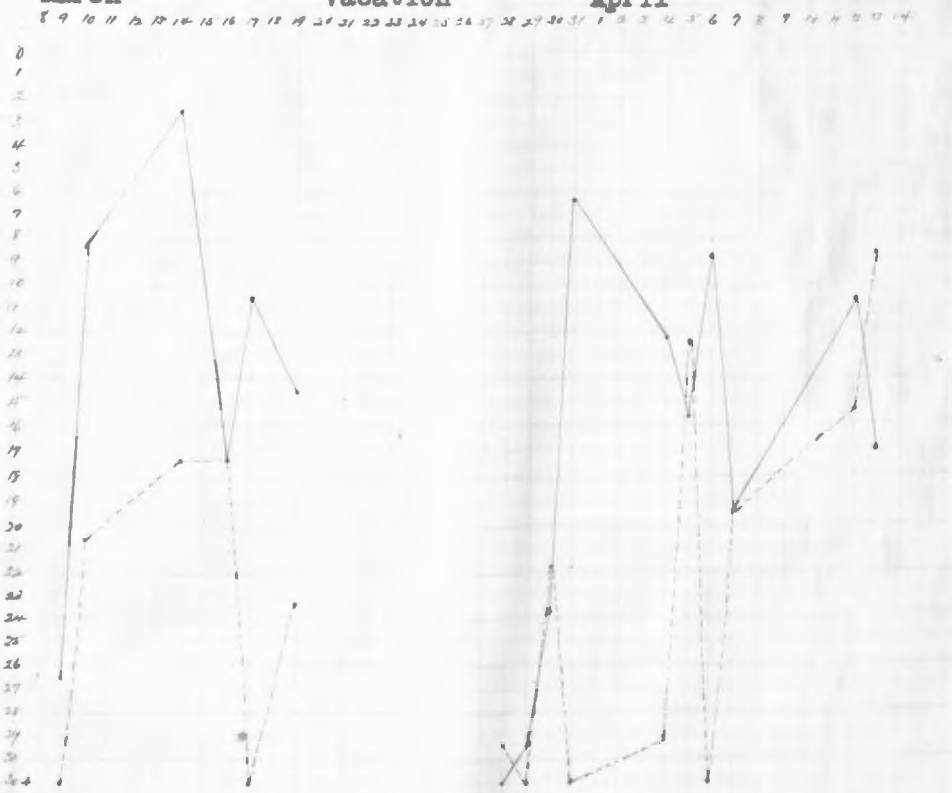
No. 58

	No. of Judgments	Med. Var.	Med. Record
Mar. 8	2		30+
9	4	2.75	20.
10	4		30+
14	4	1.25	5.25
15	4	2.5	5.25
16	4	1.75	5.25
17	4	2.25	10.00
18	4	2.25	4.00
	Series of 10 Judgments		
Apr. 4	5	2.3	8.8
5	7	4.	6.4
7	5	1.7	4.
	No. of Judgments		
14	6	1.25	2.5
		Sonometer	
Mar. 8	2		30+
9	4	5.25	4.
10	4	6.75	13.25
14	4	.5	2.
15	4	.5	2.5
16	4	1.25	2.75
17	4	1.63	2.75
18	4	1.25	5.25
	Series of 10 Judgments		
Apr. 4	5	3.6	12.1
5	3	2.5	8.9
7	4	9.2	14.
	No. of Judgments		
14	6	3.75	5.25

Practice Curve for forks and sonometer.

No. 19

March Vacation April



_____ Curve for forks ----- Curve for sonometer

Figures at the left indicate vibration differences. * Judgments in terms of intensity. Mar. 17 "Had a hard quiz preceding test."

Original class record 17.25 v.d. forks 30+ v.d. sonometer

First day's record 26.5 v.d. " 30+ v.d. "

Last day's record

Curve shows 16 periods of practice. At no time after the first day was the subject interested in the test. Lack of care attitude.

Table XIX

Forks

No. 19

	No. of Judgments	Med. Var.	Med. Record
Mar. 9	2	0	26.5
10	4	3.	8.25
14	4	.5	2.5
16	4	5.	17.25
17	4	6.	10.5
19	4	2.25	14.5
	Series of 10 Judgments		
28	4	17.9	37.
29	2	9.	29.4
30	4	7.8	23.7
31	5	2.1	6.3
Apr. 4	5	3.2	12.1
5	6	5.2	15.7
6	5	0	8.9
7	6	3.4	19.4
12	8	3.	10.8
13	6	4.1	17.
	No. of Judgments		
14	6		

Table XIX a

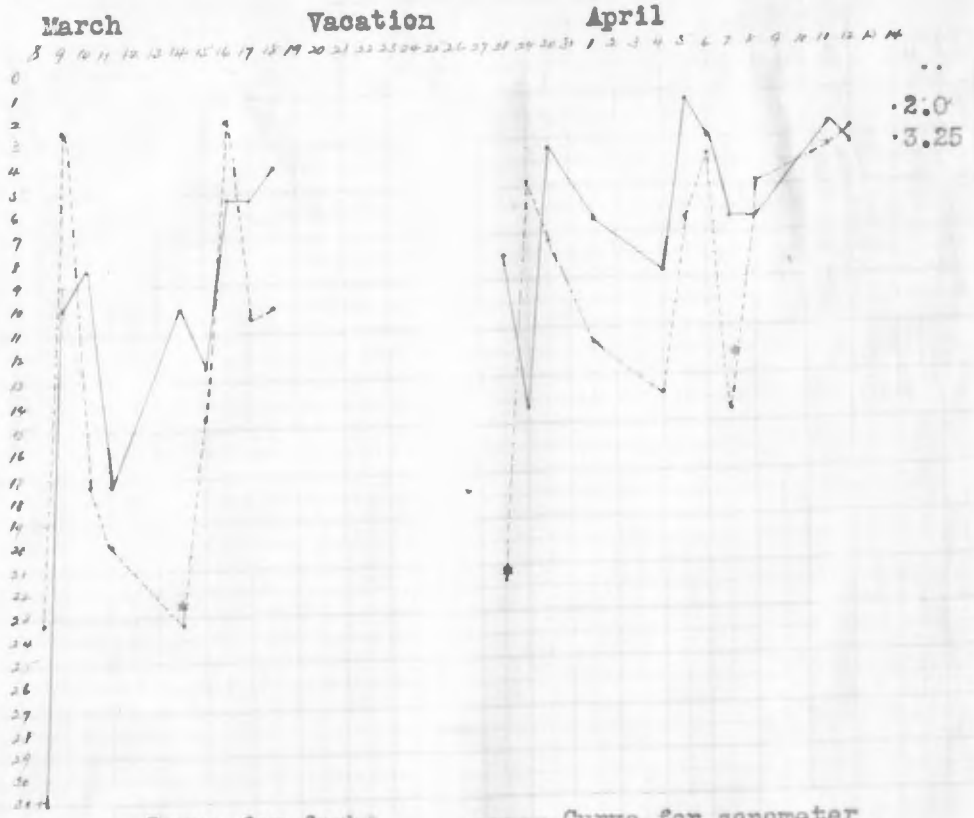
Sonometer

No. 19

	No. of Judgments	Med. Var.	Med. Record
Mar. 9	2		30+
10	4	6.	20.5
14	4	2.75	17.25
16	4	5.	17.25
17	4		30+
19	4		23.25
	Series of 10 Judgments		
28	2	9.4	29.4
29	2	4.7	33.7
30	5	16.4	21.8
31	4	7.1	33.7
Apr. 4	5	14.2	29.
5	6	3.4	12.3
6	4	12.1	32.5
7	4	1.	19.4
12	5	6.4	15.3
13	5	2.3	8.9
	No. of Judgments		
14	6		

Practice Curve for forks and sonometer.

No. 39



_____ Curve for forks ----- Curve for sonometer

Figures at the left indicate vibration differences. " Judgments in terms of intensity. Intensity constantly disturbing factor. "Forks seem piercing at times." "Louder tones are lower."

Original class record	30+	v.d forks	23.25	v.d. sonometer
First day's record	30+	v.d. "	23.25	v.d. "
Last day's record	3.25	v.d. "	2.0	v.d. "

Curves show 20 periods of practice.

Table XX

Forks

No. 39

	No. of Judgments	Med. Var.	Med. Record
Mar. 8	2		30+
9	4	0	10
10	4	1.75	8.25
11	4	8.6	17.25
14	4	2.2	10.
15	4	2.25	12.25
16	4	1.25	5.25
17	4	2.	5.25
18	4	.75	4.
	Series of 10 Judgments		
28	5	4.	8.
29	4	4.3	14.3
30	3	.8	3.4
Apr. 1	5	.3	6.4
4	5	3.4	8.7
5	2	.1	1.3
6	2	1.0	3.
7	5	2.9	6.3
8	5	2.1	6.3
11	4	.6	2.5
12	4	1.3	3.4
	No. of Judgments		
14	6	2.5	3.25

Table XX a

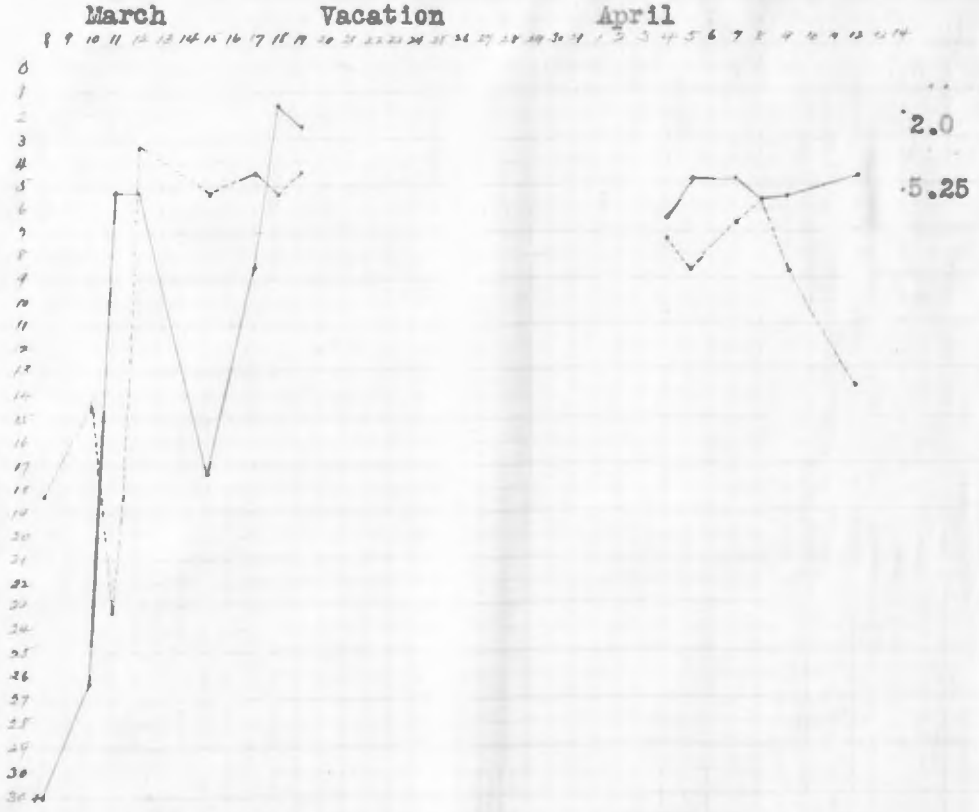
Sonometer

No. 39

	No. of Judgments	Med. Var	Med. Record
Mar. 8	2	3.25	23.25
9	4	2.	2.38
10	4	5.	17.25
11	4	2.75	20.
14	4	3.25	23.25
15	4	4.	14.5
16	4	1.25	2.0
17	4	9.87	10.38
18	4	4.25	10.
	Series of 10 Judgments		
28	1	0.0	21.8
29	3	2.3	4.9
30	4	2.	7.2
Apr. 1	6	4.	11.6
4	5	4.	13.6
5	3	3.	6.4
6	6	1.25	3.8
7	2	.8	14.4
8	1	0.0	4.9
11	3	1.1	3.4
12	2	1.2	2.6
	No. of Judgments		
14	6	.5	2.0

Practice Curve for forks and sonometer.

No. 148



_____ Curve for forks ----- Curve for sonometer

Figures at the left indicate vibration differences. Judgments in terms of intensity. Intensity constantly confusing. Illness of one week after Easter. "Louder tones sound higher." April 7 "Can anticipate pitch of second tone." Hearing of right ear poor.

Original class record	20.0	v.d. forks	30+	v.d.	sonometer
First day's record	30+	v.d. "	18.25	v.d.	"
Last day's record	5.25	v.d. "	2.0	v.d.	"

Curves show only 14 periods of practice.

Table XXI
forks

No. 148

	No. of Judgments	Med. Var.	Med. Record
Mar. 8	2		30+
10	4		26.5
11	4	1.25	5.25
12	4	2.5	5.25
15	4	5.	17.25
17	4	6.	8.5
18	4	1.25	1.63
19	4	1.25	2.5
	Series of 10 Judgments		
Apr. 4	5	2.6	6.3
5	1	0.0	4.9
7	1	0.0	4.9
8	2	.7	5.6
9	4	.7	5.5
12	2	.3	4.6
	No. of Judgments		
14	6	2.0	5.25

Table XXI a

Sonometer

No. 148

	No. of Judgments	Med. Var.	Med. Record
Mar. 8	2	8.25	18.25
10	4	2.75	14.5
11	4	3.25	23.25
12	4	1.25	3.25
15	4	1.25	5.25
17	4	2.	4.5
18	4	5.	5.38
19	4	2.	4.5
	Series of 10 Judgments		
Apr. 4	2	2.2	7.3
5	3	3.5	8.6
7	1	0.0	6.6
8	2	.7	5.6
9	4	.5	8.8
12	3	1.7	13.6
	No. of Judgments		
14	6	1.25	2.0

The curves for the forks for subjects 184, 171, 58, 38 and 148 show the practice effect in a general tendency upward. For the sonometer, the curve of 184 seems the best. Those subjects who had the most difficulty in eliminating the intensity factor and keeping their attention upon the pitch factor, show the greater irregularity in their curves. The poor records of certain days can be accounted for by the introspections of the subject. These introspections accompany the curves. Take for example, the record of subject 171 on April 1st. The subject had a headache and was not well. Again, the record of subject 39 on April 7th sonometer. Her introspection was "I seem to be judging intensity and not pitch."

The tables accompanying the curves show the median record of each day, the median variation from that median record, and the number if judgments involved. In the second method the table shows the number of series of ten taken into account. The reliability of the record can thus be determined.

A comparison of the average of the median records of the first and third double series with the forks in the original

test, and a comparison of their average variations will show the practice effect of two hours. Two days intervened between the records of the first series and that of the third series. A comparison of 236 cases shows an average record of 6.14 v.d. for the first series with a variation of 3.68. For the third series the average record was 4.5 v.d. and the average variation 3.14 v.

Conclusions and Summary.

The training with the six subjects show considerable individual variation. Is this individual variation due then, as Seashore suggests, * chiefly to the structural difference of the end organ? It would not seem so from the indications of our present results. The factors to be taken into account are, the end organ, the specific nerve centers and the association centers. It is universally accepted by physiologists and neurologists that the nervous system can be modified and made more efficient during the life of the individual and that new association paths may be established. We do not know that the end organ is modified, except when made less efficient thru abuse (not shown till later in life perhaps)

* Seashore, op. cit. p 62

and injury, nor do we know that it is not modified by training, unless we accept the microscopic investigations of the histologist as sufficient evidence. It is doubtful whether we should accept the fact that no structural difference is discernible under the microscope as conclusive evidence that there is no modification. In the central nervous system, however, there is undoubtedly a change. Thru practice we are able with in certain limits, to establish habits of attention. From the meagre evidence of the present test, I cannot but believe as does Pillsbury* that the individual difference is due to training the attention along the specific line, rather than to important structural differences of the end organ. The musical training and environment have given special ability to attend to the discrimination of sounds.

The sonometer test seems slightly better than the fork test as given for pitch discrimination. However, the change in the method of establishing the tones of the forks would probably make the fork test as good as that of the sonometer. The fact of such close correlation seems to indicate that both are good tests.

The average pitch discrimination is 6. for the forks and 5.8

* Pillsbury, op. cit. p 41

for the sonometer, with 4.7 v. and 4.2 v. as the average variation respectively. The extremes ranged from .25 to more than 30 vibrations.

The correlation between the discrimination for pitch with the forks and with the sonometer was.94 ; .47 for the forks and intensity; and .65 for the sonometer and intensity. It seems that common factors of the three tests are rather prominent. The central factor is probably attention.

Eighty-five percent of those having the best discrimination have had the most extended musical experience.

The ages of the six subjects were 22, 20, 34, 22, 20 and 23 years. Every one of those trained with exception of one, reached a discrimination that was better than the average of the 276 college students tested. Seashore concluded from his work that training was practically of no value at so late an age and that since tha organs of Corti had passed the age of their highest efficiency the training was useless. I am inclined to think that it comes down primarily to a training of the attention in selecting the one factor of pitch and holding it in the focus. The experiment as given would indicate that as soon as the subject

had his attention called definitely to the factor of pitch, he commenced very soon to improve in his discrimination. Considerable effort was manifest for some to keep that one element in the focus of attention and eliminate particularly the confusing factor of intensity. This may explain some of the relapses that are shown in the curves.

Appendix A

Psychological Labratory University of Minnesota.

Name Age Date Hour Class

Please give as specific and detailed information as possible in regard to your:

I. Musical Training

1. In public schools

2. Private vocal lessons (when? where? how long?)

3. Private instrumental lessons (when? where? how long?)

II. Musical Environment

1. Instruments in your home, and their use

2. Musical encouragement at home. (Trained voices in family.)

3. Opportunities for hearing music of any sort (Specific)

III. Musical Expression

1. Favorite selections you can sing (by ear? by note?)

2. Favorite selections you can play (by ear? by note? instruments?)

3. Singing or playing in public (parts? occasions?)

4. Ability to reproduce tune "in your head."

IV Enjoyment of Music (What actually appeals to you?)

1. Vocal (solo? quartette? chorus? opera? classical? popular?)

2. Instrumental (solo? symphony? band? chamber music?)

3. Characteristic effects of music (mental, physical)

4. Keeping the rhythm by marching, dancing, or beating time.

5. Effect of your musical knowledge?

6. Effect of not seeing the performer?

Appendix B

Instructions read to the group before the fork test.

We wish to try three tests, two for discrimination of differences in pitch of tones, and one for discrimination of differences in intensity of sounds.

First test:- A series of forks will be sounded in sets of twos, commensing with the two which are the greatest difference apart and passing thru smaller intervals until we reach some similar forks, and then back to the forks of the greater difference. (Illustrate) This plan will be repeated several times. Two trials will be given before each judgment is recorded. The word "one" (on to "Twenty-two") will be given as a ready signal before the first tone is sounded, and the word "repeat" before the second trial. Note down your judgments regarding the second fork in relation to the first fork by "S" for same, "L" for lower, and "H" for higher. Whether the second tone is higher than the first or lower will depend throughout the test entirely on chance so that each judgment should be given independently of what went before. (Illustrate) Commence the record, on the papers given you, in the top space of the first vertical column and go down. Note any disctraction af attention by putting a circle around the initial, L, S, or H. (Illustrate) Avoid humming as it vitiates all the records. Those who find it difficult to hear distinctly will please take front seats. Each one must face the resonator directly. Our purpose is to secure independent results, so take great care not to copy or prompt each other, or compare the records in any way before the test is completed. To illustrate we will give a trial test. ---------- Are there any questions?

Read before the Sonometer Test.

Second Test:- We will take an instrument known as a sonometer and proceed as with the forks. The tone will be established by drawing a bow across the string in this manner. (Illustrate) Two trials will be given as before. Observe the same precautions. Are there any questions?

Appendix B continued

Read before the Sonometer Test.

Third test:- A series of sounds of different intensities will be given in sets of twos, commencing with the two of the greate est difference and approaching those of the same intensity. (Illus) Some will be the same but we will continue the series until they are of the greater differences again. Note down your judgments of the second sound in relation to the first sound by "S" for same, "M" for more intense, and "L" for less intense. Two trials will be given before each judgment is recorded. The sounds are given in this manner. ------ Are there any questions?

Appendix C

Instructions Read before the Training Experiment.

The same instructions as used in the group test were read with the following omittions and additions; only one trial will be given before noting down your judgment so no "repeat" signal will be given. After each judgment is recorded you will be given the correct judgment which compare with the one you have noted down. In case of error draw a line through the initial, otherwise leave it, and then proceed to the next trial.

With the sonometer we will proceed as with the forks.

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