Analysis and comparison of the elements involved in the hearing and the singing of the pitch of a tone

Elmer Guy Cutshall

State University of Iowa
ANALYSIS AND COMPARISON OF THE ELEMENTS INVOLVED IN THE HEARING AND THE SINGING OF THE PITCH OF A TONE

by

Elmer Guy Cutshall, B.A.

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Iowa City, Iowa, June 8, 1914.
I Apparatus and method

II Records

III Results

A Gain through practice in singing a small interval.
   1 Elements of gain through practice.
   2 The way these elements assist the singer.
   3 Utilization of previous gain through practice.

B Characteristics of the curve.
   1 Rapid gains and apparent losses.
   2 Approximate physiological limit.
   3 Relation of average error and constant error.
   4 Automatization.
   5 Cognitive elements
      a Lack of composure.
      b Effort.
      c Attention.
      d Confidence.
      e Images.
      f Illusions

C Comparison of hearing and singing ability.
   1 Comparison of the methods of measurement.
   2 Relation of the least perceptible and least producible interval in pitch.
   3 Relation of the threshold of hearing and the average interval deviation.
   4 Relation of the average error of reproduction and the least perceptible difference in pitch.
   5 Identical and non-identical elements in hearing and singing of pitch.
   6 Leniency of the ear in singing.

D The transfer of training.
   1 Conditions favorable.
   2 Conditions unfavorable.
   3 Analysis of transferable elements.
OBJECT OF REPORT. The object of this report is to compare discrimination of pitch in hearing and discriminative action in singing of pitch, or in other words, to compare hearing of pitch differences and the ability to sing differences in pitch.

I. APPARATUS AND METHODS. These measurements were made with the tonoscope+ with the accessories of two sets of tuning forks1, the 128 v.d. set appropriate for male voices to imitate, the 256 v.d. set adequate for the women to reproduce, and the resonators2 of shape and volume to pick up, clarify and strengthen the tones struck.

All the observers were untrained and were selected without reference to interest or ability in singing, hence some were good, others were poor.

Each test consisted of forty reproductions of each tone, the higher, the lower, with the preliminary pitch discrimination for each single trial of singing. Two forks were struck and put to the resonator, the observer told whether the second was higher or lower in pitch. They were again struck and presented in the same order as before, and the observer sang them without saying anything about their order. "Regular order" means that the low

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+ See last page.
1. The forks have certain advantages over other instruments for producing the standard tone, in that they are easy to keep in correct pitch, are pure in tone and equally unfamiliar to all observers.
2. During the first few tests no resonator was used. The resonator has several advantages; it makes the tone more distinct and presents it more uniformly to the singer's ear. The increments were always small, necessitating but one resonator for each set.
standard is presented before the higher standard in time, "reverse order" that the higher one is presented first. Four tones from the two standard forks and two reproduced tones thus make what shall be consistently called in this report a "trial." In each trial the order of the tones presented simply for discrimination determines the order of their second presentation for singing, otherwise the singer would make two separate pitch discriminations in each "trial." When it comes time to sing this gives the singer the advantage of knowing the direction of the second tone, before they are presented, enabling him to give his entire attention to them with the view of reproducing instead of giving a part of his attention with the idea of discriminating. The object of the accompanying pitch discrimination was not so much to test the singer's hearing ability as to get him familiar with the standards and the interval. Separate pitch discrimination tests at the close of the series were given to each individual to determine the difference limen.

A preliminary pitch discrimination test decided what increments to use in the case of each individual at the beginning of this series. An increment slightly larger than the pitch discrimination threshold was given. From time to time this increment was made smaller as the singer got more mastery over the interval.

The tones were given with only that amount of intensity necessary to make them distinctly heard. They were of relatively equal intensity, or uniform duration, or small time interval and or sharp definition. Their length and intensity varied for different individuals.

In no case did the singer begin to sing until after the crowning of the second tone or the second presentation of the forks. As many trials were given in each test with the higher tone second as with
it first. Trials with the low standard first were bunched as were also
those in which the high standard came first. For example, ten successive
trials were given, in every one of which the lower tone came first. Then
as many successive trials were given in which the higher tone came first.
This was done to necessitate less adjusting on the part of the singer.
The observer sang just long enough for the record to be read. The less
the tone wavered and the nearer it was to the standard the less time was
consumed in reading. In the reproductions the vowel "a" as sounded in
"all" was used. This was because the observers imitated the experimenter
who used this sound in instructing them in the singing.

It was in the mind of the experimenter to make this series of
tests one of training in which approximate physiological limits in sing-
ing should be reached in the least time possible. Hence it was his con-
cern from the beginning to give the observer certain legitimate aids or
helps. Seashore and Jenner found that the eye is an aid to the ear in
singing. Instead of letting the observer use his eye by looking directly
at the tonoscope while he was singing he was told after each accepted
trial what he sang, which is about the same thing, for the standards were
never changed in any one test and the observer was told at the beginning
what they were. Thus he could easily calculate his error each time and
profit by knowing it. The observer was given the privilege, and urged
to take advantage of it, of having a trial over again if his reproductions
did not suit his judgment, providing he asked for it before his singing
was recorded on the blank by the experimenter. A rejected trial was re-
corded only by a dash on the record sheet. Short practice periods of two
to five minutes were given before the test proper, in which the individual
got used to the standards and their interval. Later on in the series
their constant error curve was shown to them when it was evident that
it would not have a tendency to discourage them and almost from the start they were told their average error from day to day. The individuals were allowed to "hum" the tones after the forks. With some this "humming" bridged over the time interval between the sounding of the standards and the reproduction of them.

The experimenter tried to be consistently cheerful from day to day. The observers were encouraged to do their best, they were urged to be on the alert. If they became excited in trying too hard to sing they were told to keep calm.

Certain reproductions were eliminated by the experiments in the sense that they were not recorded arithmetically, and used in computing the average and constant errors. Such tones were those sung in irregular order, with no interval, and certain others which will be mentioned. Irregular order means that the two tones were sung in an order other than that in which they were presented for discrimination, as for example, singing the higher tone first when it was presented second to the resonator, or singing it second when it was presented first. It is easy to see how recording tones sung in "irregular" order brings a serious source of error into the computation of the constant error. Duplications or non-interval reproductions were eliminated on the ground that they falsely indicate the ability to sing a very small interval. Take for example a test of forty reproductions in which the observer is attempting to sing standards with an interval of .5 v.d. Should he sing twenty times with an interval of 1 v.d., and twenty with no interval, the figures would show that he sang an interval of .5 v.d., if the non-interval reproductions were recorded. But this is not the truth. The observer was not singing consistently even as small an interval as 1 v.d. Non-interval reproductions are as much a sign of inability to sing the required interval as reproductions which have too large an interval. Reproductions in which the singer
movea slowly up or down the scale toward the standard, in an effort to "find" it, were not recorded. Variation in the intensity of reproduction was not allowed as a substitute for a real clean-cut adjustment, involving a new organization of the throat muscles. Now and then an observer, when singing a very small interval, being afraid to make a new adjustment lest the interval be too great, tried to get the second tone by simply increasing the intensity of the first. Tones that wavered too much for consistent reading were not accepted. Wavering is a formidable source of error with certain singers and the experimenter has to watch lest he fall into the fallacy of reading the tone as it strikes the standard on its way to and fro. Now and then a tone was rejected on the ground of its being too faint or too short.

After the training series, when the experimenter was satisfied that the singer had reached his limit in singing the smallest possible interval with the least possible average error, a test or two was given to some of the observers in order to determine how much of the efficiency gained through practice is permanent and transferable. In this test series, as it shall be called, forks were used under favorable and under unfavorable conditions as shall be explained later. Otherwise there was no change in method.

II. RECORDS. The records of this report consist in ten individual curves showing the interval, average error and constant error from day to day, one general practice curve showing the average error and the constant error of the ten observers for the first ten tests that each took, one general chart showing the relation of the pitch discrimination threshold of each individual to their singing in its various phases, a general interval deviation curve showing the
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Pitch Discrimination Ability

Finch ten tests

Average Internal Deviation

Four best successive tests

Average Internal Deviation

Entire test

Average Internal Deviation

Low Tone

Average E.E. Entire Series

High Tone

Average E.E. Entire Series

Low Tone

Average E.E. Entire Series

High Tone

Average E.E. Entire Series

Low Tone

Average E.E. Entire Series

High Tone

Average E.E. Entire Series

Both Tones

Average E.E. Entire Series

Both Tones

Average E.E. Entire Series

Both Tones, any test.

Smallest Internal deviation

Both Tones, any test.

Smallest E.E.

Both Tones, any test.

Smallest A.E.

Number of tests, singing
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# Individual Test Record Sheet

**Experiment:** Pitch Discrimination & Singing Ability  
**Observer:** 

**Date:** Jan. 24, 1964  
**Hour:** 4:30 P.M.  
**Experimenter:** E. Maxwell Mitchell

|     | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
| 1   |   |   | 9.1 | 1.8 |   |   | 2.1 | 1.1 |   |   |   |   |   |   |   |   |   |   |   |   |
| 2   |   |   | 9.2 | 1.2 | 3.5 | 2.8 |   |   |   |   | 6.1 |   |   |   |   |   |   |   |   |   |   |
| 3   |   | 30.2 | 2.2 |   | 5.2 | 4.2 |   |   |   | 6.1 |   | 1.9 | 3.2 | 1.0 |   |   |   |   |   |   |
| 4   | 1 | 7.9 | 0.1 | 2.1 | 1.1 |   |   | 6.9 | 1.1 | 1.3 | 1.3 |   |   |   |   |   |   |   |   |   |
| 5   | 8.1 | 0.1 |   | 1.8 | 0.8 |   |   | 32.9 | 4.9 | 5.8 | 4.8 |   |   |   |   |   |   |   |   |   |
| 6   | 8.1 | 0.1 | 2.1 | 1.1 |   | 7.2 | 0.8 | 1.1 | 0.1 |   |   |   |   |   |   |   |   |   |   |   |
| 7   | 7.9 | 0.1 | 2.1 | 1.1 |   | 6.9 | 1.1 | 30.1 | 0.9 |   |   |   |   |   |   |   |   |   |   |   |
| 8   | 7.8 | 0.2 | 2.2 | 1.2 |   | 8.1 | 0.1 |   | 30.6 | 0.4 |   |   |   |   |   |   |   |   |   |   |
| 9   | 7.8 | 0.2 | 1.1 | 0.1 |   | 30.2 | 2.2 | 2.1 | 1.1 |   |   |   |   |   |   |   |   |   |   |   |
| 10  | 7.9 | 0.1 | 30.8 | 0.2 |   | 7.8 | 0.2 | 30.9 | 0.1 |   |   |   |   |   |   |   |   |   |   |   |
| 11  | 4.1 | 3.6 | 29.1 | 1.9 |   | 5.9 | 2.1 | 1.4 | 0.4 |   |   |   |   |   |   |   |   |   |   |   |
| 12  | 8.1 | 0.1 | 2.7 | 1.7 | 14 |   | 7.2 | 0.8 | 1.3 | 0.3 |   |   |   |   |   |   |   |   |   |   |
| 13  | 6.1 | 1.9 | 2.6 | 1.6 |   | 30.1 | 2.1 | 2.6 | 1.6 |   |   |   |   |   |   |   |   |   |   |   |
| 14  | 4.1 | 3.9 | 22.1 | 1.2 |   | 6.1 | 1.9 | 9.9 | 1.1 |   |   |   |   |   |   |   |   |   |   |   |
| 15  | 4.6 | 3.4 | 8.1 | 2.9 | 7.4 | 0.6 | 9.8 | 1.2 |   |   |   |   |   |   |   |   |   |   |   |   |
| 16  | 6.1 | 1.9 | 2.8 | 1.2 | 7.1 | 0.9 | 30.2 | 0.8 |   |   |   |   |   |   |   |   |   |   |   |   |
| 17  | 8.1 | 0.1 | 3.9 | 2.9 |   | 7.9 | 0.1 | 1.1 | 0.1 |   |   |   |   |   |   |   |   |   |   |   |
| 18  | 8.1 | 0.1 | 2.7 | 1.7 | 7.9 | 0.1 | 3.8 | 2.8 |   |   |   |   |   |   |   |   |   |   |   |   |
| 19  | 6.8 | 1.2 | 1.1 | 0.1 | 9.9 | 1.9 | 2.8 | 1.8 |   |   |   |   |   |   |   |   |   |   |   |   |
| 20  | 30.8 | 2.8 | 3.7 | 2.7 | 9.8 | 1.8 | 3.7 | 2.7 |   |   |   |   |   |   |   |   |   |   |   |   |
| 21  |   |   |   | 95% |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

95%
Average least producible for three best tests.

Least producible for best single test

T. B. H. N.W. G.W. R. A. C.S. G. M.W.

Curve comparing least perceptible and least producible differences in pitch. The continuous line represents the least perceptible difference. The spaced line represents the least producible difference.

XV
The spaced line represents the average interval deviation for the first ten tests.

The spaced line represents the average interval deviation for those ten tests after the approximate physiological limit is approached.

Curve comparing average interval deviation with pitch discrimination threshold. The continued line represents the threshold of every singer.

XVI

The spaced line represents the average interval deviation for the four but successive tests after a p. limit is approached.
The spaced line represents the average error of the first ten tests after the A.P. limit is approached.

T. B. H. M. H. W. R. A. C. S. G. M. W.

The spaced line represents the average error of the first ten tests.

20 2.1 20

3.9

3.7

15 1.6 15 2.9

4.8

5 6 6 6 7 7 12 1.4 1.5

Curve (the showing) relation of the average error to the pitch discrimination threshold. The unbroken line represents the threshold.

XVII
average interval deviation of the ten observers for the first ten
tests that each took, a summary table showing how the individual
test records were gathered together and kept all on one sheet, a
single test record sheet showing how records were written down dur­ing
the test and afterwards figured out, a curve showing the rela­tion
of the least perceptible and least producible difference, one
comparing the average interval deviation with the hearing threshold,
and one showing the relation of the average error and hearing threshold.
It is impossible to put in this report all the figures which are the
basis for the curves, anyone wishing to see them will find them on
file in the Psychological laboratory.

The individual curves are arranged alphabetically, the
latter or last initial determining the order in case more than one
letter is given, and are all on the same plan and scale. They aim
to show the individual's gain from day to day by means of the spaced
line representing the constant error and the continuous line denot­ing
the average error. The heavy horizontal lines, continuous,
broken, and spaced, represent the standard tones. The figures at
the bottom denote the number of tests given, the others the interval
between the standards imitated. A vertical distance equal to one
side of the square stands for l. v.d., a horizontal distance of the
same length represents one day's practice. These days came once
each week. Only one test was given on any one day.

The general practice curve is built on the same plan as the
individual curve and is marked G.P.C. It shows the general tendency
toward efficiency during the first ten days of practice. It was not
continued beyong ten days; for two of the observers did not continue
their practice further, on the tenth day there was a general tendency to reach the physiological limit, the gain from then on being slow, and also after that time new and small intervals were introduced resulting in a disturbance in the singing. A study of these disturbances can be made by going to the individual curves. This curve then represents the periods of more rapid and consistent gain. On the same sheet is found the general interval deviation curve (G.I.D.C.) with the same plan and scale. If an observer was imitating tones from two standards whose interval was 3. v.d. and the average interval of the reproduced tones for that particular test was 1.5v.d. it was assumed that the interval deviation was 1.5 v.d. This curve then shows how much an interval error the average observer sang during the time of rapid gain.

The curves and general relationship chart are based upon twelve thousand single reproductions of the two standards, and fifty-two hundred single trials of pitch discrimination given in tests at the end of the practice series when no singing accompanied. It was not intended that the pitch discrimination trials given with the singing should be used in determining the threshold of hearing. One example of the individual record sheet is sufficient to show how the singing tests were recorded. The numbers written in the columns under the figures representing the standards were recorded during the test immediately after each trial. All other computations were made after the test.

A summary table was kept for each observer. This shows the day, hour, and year of the experiment, the number of tones sung on each day, with the average error, constant error, average sharp
average flat, number of sharps, number of flats, interval of the standards, interval of reproduction, interval deviation, and the record of the accompanying pitch discrimination test. These furnished the data for the curves.

III. RESULTS.

A. Gain through practice in singing a small interval. The individual curves show that every singer made considerable gain in the training series. This gain may be summed up in the two phrases, better control of the voice in singing small differences of pitch, greater efficiency in imitating the standard tone. These gains, within certain limits, work together, the one enhancing the other. Learning to sing a small interval means better throat control, just the kind of control which is a necessary factor in making the voice imitate more correctly the standard which the singer has in mind.

A., C.S., C.H. and R. do not begin their singing with as much error as the other observers. Violin training and ease in singing a small interval account for this in the case of the first two, more than average ability in singing a small increment for the last two. Violin training is uniquely adapted for training the ear to judge small differences of pitch. This is not the case with piano practice. What training the others had was confined to the piano.

In computing the gain quantitatively the average error and constant error on the first day are compared with those of the last two or three days of approximate physiological limit singing before the difficult small interval is introduced. On the high tone the gain in average error for the ten observers is approximately five hundred per cent, on the low tone it is four hundred and sixty per cent. The gain in constant error on the high tone is about one
thousand per cent, on the lower tone it is about the same. Only a small part of the gain can be shown by figures dealing with the quantity aspect. The quality of singing is greatly improved as regards steadiness, uniformity, distinctness and consistency of tone.

One of the chief difficulties for the observer to overcome was the tendency to sing the interval much too large. Gain in this respect was very rapid at the start and on the third day of singing, as shown by the general interval deviation curve, the interval deviation was reduced over three hundred per cent. From the fourth to the sixth day the gain was very slow, but on the seventh day a leap toward efficiency was made. Unlike the average error and constant error curves, the general interval deviation curves do not show a continual consistent gain in efficiency. It has been indicated that the gain through practice was almost phenomenal; it now remains for the gain to be analyzed into its various elements, showing just how each element assists the singer.

1. The elements of gain through practice are; an acquaintance with the tonoscope, with the ability to hold the speaking tube in the proper way, a knowledge of just what is demanded in the test, the ability of attending to the pitch discrimination and reproduction without strain or too much effort, the ability to compare one's reproductions with the standard tones and to accept or reject as the case may demand, the ability to organize and control the muscles of the throat to sing a small interval and to imitate more accurately the standard, automatization through a continual repetition of the standard tones from day to day, schematization or economizing the attention by giving it largely to the first tone and singing the second as far above or below it as the
judgment may direct, increased efficiency in telling the direction of the second tone, partial control of the illusion of thinking a small interval is larger than it really is, ability to sing a small interval smaller, more firmness of reproduction and less wavering, ability to make a clean distinct adjustment in going from one tone to another rather than attempting to substitute variation in intensity for change in pitch, hitting upon certain helpers such as humming and unique methods of imagery, better tonal attack, greater ease and quickness in reacting to the stimulus, less fluctuation in making the adjustment, ability to keep the tones from fusing, confusing or becoming washed out too quickly, the adoption of a uniform loudness in reproduction, use of one vowel sound consistently, which was \( \text{“aw”} \) sounded in \( \text{“all”} \), and learning to interpret kinaesthetic sensations by associating a particular strain with the pitch which it produces.

2. The way these elements assist the singer.

Acquaintance with the tonoscope is important. The singer learns how to hold the speaking tube, the significance of which is brought out in a test, where, on not holding the tube in the accustomed manner, the observer said, "Oh, I did not have my hand adjusted rightly, it didn't sound right to me, let me have that one." The reading corroborated the feeling of the individual, he did not sing the tone in question correctly. The singer naturally wonders how and why his voice is recorded on the tonoscope. This legitimate curiosity must be satisfied partly by adequate explanation, partly by getting used to the instrument in the course of several practice periods. The observer must get used to the humming sound of the instrument which at first, is a
distraction, especially to hearing the standard tones. This distraction soon changes into an aid, a means of making the individual feel at home. Without this, he would not sing as well, his habits would be disturbed. Something would seem wrong. Also, the singer learns to put his voice forward, to throw it out, to make it breathy enough to register. There is a tendency at first for the singer to sing in the back part of his throat, to swallow his voice, to keep it down and submerged and hidden away. He soon learns that a rather weak tone put out through his teeth registers better than a loud one half swallowed. The observer also overcomes the false conception that the way to change the pitch higher or lower is to make the tone louder or weaker. Considerable practice is necessary for the singer to actually practice this truth in his reproductions. Change in intensity is not change in pitch.

Gain demands that soon the observer have a working knowledge of what is required of him in the test. He comes to the first test with no understanding of the condition and requirements. Plenty of instructions are given him, but the act of remembering and carrying them out drains upon his conscious attention. Efficiency demands that they be taken over into the habitual, leaving the conscious to attend to the fundamentals of hearing and singing. It must not spend itself in remembering such instructions as, sing the tones in the order given, hearing discrimination, sing not after the first but second presentation of the forks, sing as soon as the second standard tone is drowned, in the first presentation say the second tone is higher or lower than the first as your judgment decides. Many of the observers showed poor
cognitive ability in hearing discrimination. The end organ responded but the mind did not know how to interpret the sensation. It was some time before the cognitive threshold approached near to the physiological one so that the observer was able to tell with ease what a difference in pitch meant, its direction and amount.

It is important that the observer learn early in the series how to compare the tones of production with those of reproduction. This is not learned until each set of tones becomes more or less familiar to him. A comparison of this kind necessitates some kind of imagery for standard and sung tones. This imagery may be either visual, auditory, or kinaesthetic, or various mixtures of all three as in the case of T.

One of the chief elements of gain is better control over the throat muscles in singing a small interval. The singer invariably sang the interval too large, not entirely because his voice was not used to singing as small an increment as 1. v.d., 2. v.d., 3. v.d., or even 8. v.d., but partly because an interval of 2. v.d. seemed larger than it really was. In music the voice is never called upon to sing an increment of 2. v.d. or even 5. v.d. From the hearing side the singer has always heard large intervals. How natural then for him to be a victim of the small interval illusion when called upon to sing such a small interval. With some of the observers this was a very difficult matter. They were asked not to make an interval of, say, 1. v.d. 2. v.d. 3. v.d. but the smallest one possible. Some preliminary practice before the test proper was given to enable them to get slightly acquainted with a small interval. When the difference between the
the standards is, say 3. v.d. and the individual cannot sing an
increment smaller than 8. v.d., the average error on both stand-
ards is of necessity large.

There is a certain automatization in singing the
standards. A groove is worn in the vocal cords, the standards
get more and more familiar to the ear, and the transition from
the sensory impulse of hearing the standard to the motor impulse
of reproducing the standard is made easier and quicker. The
psychological time in reaction is lessened. Automatization means
that less attention is consumed in hearing and reproduction and
more then is left to the judging of how much the standard tones
and tones of reproduction were alike. Automatization sets the
observer at ease, habit now does what attention formerly directed.
Automatization may mean certain organization and combinations
of muscle strains in the throat, familiar feeling comes when this
previously set up organization is quite easily touched off. The
main reason for thinking that automatization takes place is that
the standard 128 v.d., which was never changed, except when
the interval was made smaller and the variant was brought closer
to it and sung first, was on the whole sung much better than
the variant, or changing standard.

Schematization is very important. At first the ob-
server gives his attention equally to the two standards. After
a while it is learned that centering the attention upon one
standard, the one coming first in time, makes for economy, and
the second tone is sung as it is judged to be so much higher or
lower than the first.
Confidence gained partly accounts for greater firmness of reproduction which is an important asset in singing. Had not the observer sung with greater firmness in the latter part of the test series, it would have been impossible to have read the reproductions when the interval was small, say .5 v.d. or 1. v.d. As the singer learns to make a small interval, he also learns to hold his throat muscles truer and steadier. Several of the observers got so that they could sing with almost the steadiness of the tuning fork.

It was important for the observer to learn that intensity, loudness, is not a substitute for a clean, distinct throat adjustment. One observer as yet has not learned this lesson. Some would slide up for a higher tone, slack up for a lower, at all events, this kind of adjustment made for too small an interval, in fact it let the singer off without any real adjustment. This kind of adjustment is along the line of least resistance, it being easier to intensify the vocal cords than to change their vibration frequency. Again the singer might resort to this kind of an adjustment being afraid that if he changed his vocal cords the change would be too great and the interval sung too large. My observers were continually asked to stop just a fraction of a second after singing the first tone, and start anew for the second.

The most important helper which some of the observers found was that of humming. Humming bridges over the interval, gets their voice before them, which is easier to duplicate, being richer than the tone of the tuning forks, and gets the
muscles in the throat ready for action. The best observers used this helper the most consistently during the latter part of the tests. This humming was not done in the first part of the series, (so consistently.)

Greater ease and quickness in reacting to the stimulus is an important gain. The quieter and the quicker the observer can go about to sing the standards, the less fluctuation there is in the tones produced, the less time elapses between the drowning of the last standard and the singing of the first, which according to experiments made by Berlage, makes for better reproduction.

The observers settled down to a uniform loudness in their singing. This fact was discovered one day when the aperture through which the jet of flame plays became clogged and the reading was difficult. The observer was asked to sing louder. This she did but missed the tone by several vibrations. She said, "If I sing louder it throws me off." The difficulty was removed, the flame became sensitive as usual, and the observer settled down to the accustomed intensity of tone and the experiment proceeded successfully.

Better tonal attack gives the singer the advantage of hitting the tone with the first discharge of his effort. A second attempt or a delayed one necessitates his adjusting his throat muscles with the aid of an image, whether it be auditory, visual or kinaesthetic, that is faded and not fresh. Learning to make just one adjustment and that while the impression is vivid, and responding once for all without doubt
makes for accuracy.

While all the observers complained of a paucity of imagery of any kind, yet as the tests went on, some useful imagery was manifest. An interval appeared to T. as a stairs step, small or large according as the interval was small or large. Comparing the visual image of the standards with that of the reproduced tones enabled him to use one more clue in judging how well he sang. G.W. saw the low tone as broad and low, the high tone as thin and high. The greater the interval the greater was the contrast between the broadness and lowness of the one and the thinness and highness of the other. If the contrast between the standard tones was equal to that of the reproduced tones G.W. judges the reproduction to be more or less correct. Contrast by means of this imagery is an element of judgment.

Using kinesthetic sensations as a sign is an important aid. Every singer has feelings of strain in the throat, which at first were either subconscious or conscious, even if conscious they were not interpreted, no meaning was read into them. Later on they began to mean something. A familiar pleasing strain indicated that the correct note was struck. This feeling of familiarity in the throat when the old familiar note is struck takes part of the burden of passing judgment from the ear and auditory and visual imagery in comparing the standards with the tones sung.

Before discussing the next topic a word ought to be said about the peculiarities of this series of tests which make the tonoscope of supreme importance as the instrument of research. Firmness of tonal attack, wavering of voice, trailing towards
sharp or flat, errors of 1 v.d. to 5 v.d. sharp or flat escape the ear of the musician to a large extent. But they do not escape the tonoscope. The record of wavering, trailing, sharpening and flattening is before the experimenter as the observer sings. As the tests go on from day to day, gain in the direction of overcoming these difficulties can be seen and recorded with accuracy. Even an error of .1 v.d. can be detected. Without a tonoscope this series of experiments would have been practically impossible.

3. In discussing the principle of the utilization of previous gain through practice, tests in which the disturbing factor of a change in interval was brought in, are entirely excluded. As a rule, when no large disturbing factor is introduced, previous gain is utilized. Small disturbances are not revealed by the curves for the increase in efficiency through practice is large. The curve shows only those disturbances which make for inefficiency as fast or faster than practice makes for efficiency. Quite often then the curve does not reveal even large disturbances. There are exceptions to the rule of utilization of gain through practice. In the case of A. on the fourth and eighth days the practice gain was not used much in either tone and no disturbing factor of any kind, so far as the experimenter knows, came into the test. On the second day in the singing of the low tone there was a decrease in efficiency. In the case of B. the low tone on the fourth day showed a falling off as compared with the singing on the third day. G. sang the high tone poorer on the
fifth day than on the fourth. C.H. sang the low tone poorer on the fourth and ninth days than on the third and eighth respectively. In the case of R. this principle was violated on the fourth, ninth and tenth days in the upper tone and on the fourth, eighth and tenth and twelfth days in the lower tones. In the case of C.S. this rule was violated on the third, sixth, fifteenth and sixteenth days in the upper tone, on the sixth, ninth and fifteenth in the lower. In the case of T. it was violated on the seventh day in the upper tonal singing, on the eighth in the lower. In the case of G.W. this rule was violated in the upper tone on the sixth day, in the lower tone on the sixth, eleventh, fourteenth and nineteenth days. On the twelfth and fourteenth days in the upper tone and the ninth, eleventh, twelfth and fourteenth days in the lower tone, H.W. violated this rule. In the case of W.W. in the upper tone on the twelfth, and thirteenth days this rule was violated, in the lower tone on the fourth, eighth, and thirteenth days. No explanation can be offered for these variations from the general rule of steady, continued, increase in efficiency, except that fluctuations are natural in the normal practice curve of any kind, that fatigue, slight cold in throat, and other physical annoyances have something to do with this inaccuracy of singing. Very likely variations in the attitude, interest taken in test, cheerfulness of singer and attention throw some light on the subject. On one occasion, after having made a poor record, the singer was asked
if he was normal, he said "yes." From the expression on his face and eyes and his general bearing, it was concluded that his record was poor because he lacked interest, he was not on the alert as on the day before.

B. Characteristics of the curve.

1. Rapid gains and apparent losses.

The gain in efficiency from day to day on either tone is not uniform. The following percentages, denote the gain of the following day over the previous one, in the singing of the high tone by ten individuals, figuring on the basis of the average error. The second day, forty percent, third, five percent, fourth, six percent, fifth, fourteen percent, sixth, nine percent, seventh, twenty-two percent, eighth, eleven percent, ninth, fourteen percent, and tenth, eight percent. The average error on the first day is five and one half times that of the tenth day. The greatest gain is made on the second day because the individual has overcome the outstanding, objective difficulties of the test, such as the hum of the tonoscope, newness of the test, continual demand upon attention to remember the procedure, and inability to sing a comparatively small but not difficult interval. These difficulties being rather superficial were speedily overcome.

The general practice curve shows that for the high tone for the ten days for ten observers the average error and constant error were steadily decreased. In no case was the error of a following day greater than the preceding one. As shown by
the general practice curve the constant error for the high tone from day to day decreases at about the same speed as the average error.

The general practice curve shows that on the low tone the gain from day to day is a continual one with the exception of the fourth day. This exception is due in fact to grossly erratic singing on the part of two of the observers. The other eight made a small gain on the fourth day. The gain of the second over the first day was five per cent, of the third over the second, thirty percent, of the fifth over the sixth, thirty percent, of the sixth over the fifth ten percent, of the seventh over the sixth, forty percent, of the eighth over the seventh, ten percent, ninth over eighth, none, tenth over ninth ten percent. The average error on the first day is almost five times as large as that of the tenth day, which is slightly less than the ratio of the first day's error to the tenth day's error in the high tone. The most rapid gains were made on the third and fifth days. Erratic singing on the fourth permitted the rapid gain on the fifth. We should expect rapid gains at first. The observer soon found out what was required of him in the test, what the conditions of the experiment were, and in general, how to overcome the objective and superficial barriers to singing. All this can be done without coming very much into the real business of singing. These difficulties are small when compared with those of imitations, and singing the least producible change in pitch. Another element of rapid gain was breaking up the habit of the voice to
sing an interval of from 15. v.d. to 30. v.d. (The intervals used at the beginning of this series were much smaller than this.) This does not mean that the voice has learned to sing the small interval of 1. v.d., 2. v.d., or even 3. v.d. but at any rate a great step was made toward lowering the average and constant errors. Inability to sing the small interval as much as any other on factor caused a large average and constant error in the first few tests. Take the case of H.W. Her average error is large. She never got control over the small interval.

We have been considering the curve for the first ten days of the ten individuals in a general way. As some observers took almost twenty tests and as an individual curve of each is made, the whole analysis has not yet been given. On the tenth day most observers have reached their approximate physiological limit as far as the average error is concerned. There is no approximate physiological limit for the constant error because of fluctuations due to disturbances. The gain, from the tenth test on, until the interval is made a serious disturbing factor, was slow or small. It was much less than the gain at the beginning of the test calculated in vibration frequency, and a little less if calculated in percentage. The disturbing factor of the small interval gave a condition which must be described as apparent rapid loss, unreliability and inconsistency of singing.

In the case of C.C. when the interval of .5 v.d. was introduced the increase in both average and constant error was large. This decrease in efficiency was greater for the second than for the first use of the interval. This does not mean that C.S. has lost
some of the efficiency gained through practice, it simply means that the disturbing factor was too great, and a demand was made which was beyond his voice to fulfil. In the case of C.H. in the fifteenth test an interval of .5 v.a. was introduced which caused the average error to become erratic. As the observer became familiar with the very small interval a part of the erratic nature of the average error was overcome. As the change of interval was the main cause of increase in average and constant error, the effect of a change of interval is now to be considered.

The change in interval brings in a disturbance. If there had not been a rapid increase in ability through practice, one would have expected the singer to have done poorer than on the previous day, whenever a change of interval was introduced. A change of interval is more of a disturbing factor after the approximate physiological limit is approached than before. This is because the change is proportionately more radical and the interval is becoming more and more difficult. With a few exceptions no decrease in efficiency occurred without a disturbing factor; generally a change of interval, as the use. This interval may or may not have been too small and difficult for the singer. If it was too small and difficult, the changes are that the singer never would have gotten back to his former efficiency while it was used. Never more than one interval was used in any single test. Each test did not necessarily have a new interval, the
same one was used in five or six tests, in which case, if the interval was not too difficult, the disturbance was limited to the first test in which it was used. With the exception of ten times the change of interval was always in the direction of a smaller increment. The object of this was to reach the singer's limit in singing a small interval as soon as possible. A change of interval was not introduced until the singer had in general mastered the old one. As the main difficulty with all but two observers was that of not singing the interval small enough, mastery means being able to sing a small enough increment. The greater the mastery over the old interval, the less is the new one a disturbing factor. Fifty-two changes of interval were introduced into the entire practice series. Twenty-five resulted in a decrease in efficiency. This does not mean that the remaining twenty were not disturbing factors. They were, but the gain in practice more than made up for the loss which they entailed. In the early part of the series the case of A. was an exception to this. As she was inclined to sing the interval too small, a change toward a smaller interval meant an aid rather than a check upon her singing. The increase of average error, due to a change in interval, was slightly more for the high tone than for the low one. More automatization of the low standard than of the variant naturally caused the least habitual tone to suffer the effects of a disturbance more than the greater habitual one.

One might wonder why change of interval necessarily effects the average error, since one has to do with singing
sharp or flat, the other with imitation of standard. The principle of divided attention is a clue to the solution. Singing the interval and imitating the standard, each should be left as much as possible to the control of habit. If the habits of the former are broken up, it necessitates the use of more secondary attention in singing the interval, leaving less attention to control the imitation of the standards. Again some intervals are easier to sing than others, and each individual may have his own favorite interval, a change meaning variation not only in the interval deviation, but also in the average error. Again a change in interval may for the first test cause the singer to have less confidence in his singing so as to make the tonal attack in each case with less decision and firmness. It also caused in some cases a greater wavering of the singing. A change of interval of necessity brings in one new and unfamiliar standard, which is more difficult to hold in the imagination than the old and familiar one.

This statement rests upon the assumption than an unfamiliar sound is not as easily held in memory as a familiar one. This results in difficulty of imitation and makes for duplications, because the second tone does not stand out clearly enough, and as there is a tendency for the voice to imitate its own tone more readily than an artificial pure tone, the second reproduction is apt to be a repetition of the first. The change of interval being in most cases toward a small one, there arise elements of confusion and excitement in the individual's efforts to keep the tones separate in discrimination and reproduction. Fearing
lest the interval be too large, the singer often makes no inter-
val at all.

2. Approximate physiological limit.

The approximate physiological limit means that the
limit which in a general way represents the singer's greatest
efficiency in singing, viewed from the standpoint of imitation,
singing the smallest possible interval, and singing the least
possible interval deviation. This limit is not an absolute
one, but approaches it more or less. This limit represents the
time when rapid gain ceases, and after which only in a very small
degree can efficiency be increased.

Not all the observers have reached their limit. Unless
otherwise designated, limit shall be used to mean approximate
physiological limit. Those who have, reached it on about
the tenth day. This limit did not vary to any great extent unless
the singer was disturbed by some new difficulty. The main disturbing
factor was a change in interval. A change of interval may dis-
turb simply because the interval is new, or because it is dif-
ficult if not entirely impossible. When a disturbance results in
an increase in the average error, it does not mean that there is
a decrease in efficiency. Failure of the limit to mean
one of two things, either that the tests did not continue long
enough, or that a disturbance was brought in too often. The
latter resulted in fluctuations when otherwise the singing w ould
have been steady.

In the case of O.H. the limit was approached in both
tones on the eighth day, and with the exception of slight fluctuations continued throughout the test. It was reached on the eleventh day in both tones in M.R.T.'s singing. The gain from then on was slow and was not caused by the acquisition of any new element serving as an aid, nor by the overcoming of any old outstanding barriers to singing, but was the result of making the imagery, throat control and general technique, already in use still finer. By the eleventh day it may be said that M.R.T. had acquired the essential elements gained through practice. On the fifteenth day he reached the point of most efficiency as shown by the average error. From the eighth day on, with the exception of the fourteenth his constant error was small, due to mastery over the interval and good imitation of the standards. In the case of B. the limit began in both tones on the fifth day and continued to the end of the tests. With her it began unusually early in the tests because she gave attention and interest coupled with just the right kind and amount of effort, and finally because she used imagery which had been gained through previous piano practice. C.S. reached his limit on the eleventh day, R. on the ninth, N.W. on the ninth, and C.W. on the eleventh. During the days of threshold singing, the constant error was very small and steady, as was also the average error. If a glance at the general practice curve is taken, it will be seen that the limit begins in the lower tone on the seventh day and lasts through the tenth tests, but in the upper tone only indications of it are seen in the ninth tests. This shows that the limit in singing was reached sooner in the lower tone than in
the upper tones. This was because the lower standard was constant while the upper one was a variant.

In summing up, it may be said that the limit denotes crude mastery over the main difficulties of singing and the general acquisition of a technique which will not be radically changed later, only refined, that this limit continues as long as no disturbing factor is introduced, that the constant error is small during the limit singing, that the deviation of the interval is small and steady and that the limit begins at least two days sooner in the lower tone than in the upper tone. This last fact is due to lower tones being sung more automatically than the upper ones.

It is interesting to note that no plateaus occur while the singer is overcoming difficulties and gradually mastering the technique. There are in general no days of simply "marking time" in the early period of the training series. It is true the gain from day to day is not always equal, yet there is some gain. Finally, let it be said that the limit is reached early in the series.

The limit in producing the smallest differences in pitch is quite another thing than that in imitating the standard. One has to do with producing the smallest possible differences of pitch, the other with correct imitation of the standard. With one or two exceptions, when the observers began the eleventh and twelfth tests, they were singing the smallest interval possible for them to sing. Some who in the eleventh test found it impossible to sing an average interval smaller than 2 v.d. sang in the later tests an interval as small as .7 v.d. The limit in producing small differences in pitch is reached after that of imitating, by ten days in the case
of T., seven days in that of C.H. and four in that of B. As the making of small differences is closely tied up with singing the correct interval, except where the interval of the standards is entirely too small, it may be said that the limit of interval deviation is reached after that of the constant error and average error, by five days.

3. Relation of average error and constant error.

The average error and constant error are very much alike in their variations. On the first day in the singing of the upper tone they were equally large in the case of all the singers. Every individual sang every high tone sharp in the first test. The general practice curve for the observers, shows that on the second day in the high tone the constant error is 1. v.d. less than the average error, on the third day it is .9 v.d. less, on the fourth day 1. v.d. less, on the fifth day 1. v.d. less, on the sixth .8 v.d. less, on the seventh .4 v.d. less, on the eighth .5 v.d. less, on the ninth .6 v.d. less and on the tenth day .5 v.d. less than the average error. The average constant error for the first ten tests for ten individuals’ singing the high tone is 2. v.d. the average error being 2.7 v.d.

Reference has been made above to only the first ten tests of ten individuals. This always is the case when attention is directed to any phase of singing as represented by the general practice curve. On the first day the constant error is 2.3 v.d. less than the average error, on the second day it is 2.2 v.d. less, on the third day 1.4 v.d. less, on the fourth 1.3. v.d. less, on the fifth, .5 v.d. less, on the sixth .8 v.d. less, on the seventh, .8 v.d. less, on the eighth .8 v.d. less, on the ninth 8. v.d. less,
and on the tenth .7 v.d. less. This applies to the lower tone. The average error for the ten observers for ten days is 2.2 v.d. The constant error is but one-half that amount or 1.1 v.d. The ratio between the average error and constant error is 2:1 for the low tone and 2.7:2.1 for the higher tone.

During the first eight or ten tests before the limit is reached the average and constant errors decrease at about the same rate. Where one is rapid the other is also. After the limit is reached the constant error is nearly zero, as seen in practically all the individual curves. After the disturbing factor of a small interval is introduced, the constant error is increased as well as the average error. In the case of both average error and constant error, when they are small, there is less fluctuation. Less fluctuation in each occurs during the limit singing before the impossible interval is introduced.

As one of the aims of this series was to find out if the voice can sing as small an interval as the ear can hear, the singer was given after the first ten tests an interval as small or smaller than he could possibly sing accurately. There are at least two factors that enter into singing, to make the constant error small, one is better imitation of the standard as such, the other is better control of the interval, singing it neither too small nor too large. The singer may sing the correct interval and both tones be sharp or flat, by almost any amount varying between .4 v.d. and 2.v.d., simply because he is not imitating correctly. He has not hit the right place on the scale. Again he may be able to imitate the tones more or less correctly if they are sung without reference
to an interval, but when he has to sing them successively at an interval smaller than he can possibly sing, his lack of ability to sing the interval small enough will of necessity throw one tone or the other, or both off by just as much as the interval is sung too large.

Summing up, it may be said that the constant error and average error deviate together, that the former on the average for all the singing done by the ten observers is 1.3 v.d., the latter 2.1 v.d. that when the average error is smallest the constant error is very near zero, that the ratio between the two is larger for the higher tone, than for the lower one, that the inability to sing correctly the given interval makes them more nearly equal and control over the interval makes the constant error much smaller.

4. Automatization.

Automatization is a logical result of continual singing of the same standard tone. This organic adjustment of a subconscious nature favors the tones sung most frequently under constant conditions. Throughout this entire series one standard was given under the same conditions as the other with one exception, namely, that the lower tone remained constant while the upper tone was a variant, being changed from time to time as the interval was made smaller. If one tone was sung with a smaller average error than the other, the main way to account for this difference is by saying that one became more automatic than the other. This is the case. The average error for the entire series for ten observers on the low tone is 1.9 v.d., on the high tone 2.3 v.d. The low tone was sung more confidently, without wavering and more
firmness than the upper one. GW said that it was easier to sing
the lower tone than the upper one. The lower tone through repeti-
tion became more familiar and easier to imitate than the upper one.
Automatization is not confined to the low tone but is characteristic
of the singing in general. Many times some of the singers said:
"My voice won't do as I want it to do." With poor singers the voice
is largely beyond the control of the ear and consciousness, with
the best of singers, it is somewhat erratic. Nearly all the ob-
servers said that they sang with less strain at the end of the test
when the best singing was done under more difficult conditions than
at the beginning. They also gave less secondary attention to the
singing at the close of the series. When a change of interval
was made, the lower tone, a constant, suffered less than the
upper tone, a variant. The limit is reached a couple days earlier
in the lower tone than in the upper one. The constant error for
the low tone is less than the average error. When a change of
interval is made, and is a disturbing factor because it is novel
and not because it is too small, the reason lies in the fact that
the former familiar interval was sung with a greater degree of
automatization.

5. Cognitive elements: Lack of composure; effort; attention;
confidence; images; illusions; interest.

Cognitive elements in singing are revealed by the intro-
spections of the observers, peculiarities found in the individual
records of single tests and observations on the part of the ex-
perimenter. Lack of composure makes for poor voice control and
inaccurate singing. Excitation tends to impair the efficiency of
habits and automatization formed through previous practice. The
records of nearly every observer reveal periods of inaccuracy, where the "reversals" and "duplications" came in clusters. As many as twelve reversals occurred successively before the singer was able to sing the correct order. It was common to find six successive failures in either making an interval or in singing the order given in discrimination. Several reasons may be offered in explanation of the fact that mistakes cluster and are not scattered out evenly over the test. Lack of interest, attention waves, and slight disturbances are minor causes, yet the main reason is that the singer got excited and lacked self-control and composure. On making the first mistake, the singer was told of his failure, as a "reversal" or "duplication" was never recorded as a part of a trial. This announcement caused him to put forth an extra and excited effort to sing the correct order with the necessary interval. If this resulted in a failure, the observer showed a blind excited attempt to do better. Some showed signs of discouragement. A. often said, "I can't sing that." On some days the singer went through the entire test without a "duplication" or "reversal." A small interval caused more lack of composure than a larger one because it was beset with more difficulties which in turn destroyed self control. Often the observer attributed his mistake to some other cause, resenting the suggestion that they were caused by lack of control and composure. In conclusion, it may be said that excellence varies with composure, and that composure varies according to the difficulties in singing.

Effort is a mental element which works for and against good singing. G.W. said: "when I try too hard, I do not
do so well." At the beginning of the series effort affected the singing entirely different than toward the close. It seldom even impaired the singing of the beginner. Those observers who tried the hardest made the most progress on the start. No habits of singing were then formed. But habits of control of small interval and imitation were necessary and effort helped to form them. Once they are formed, the singer must let them work by themselves, and must give his attention and effort mainly to getting the tones better in mind. Toward the close of the series A. often put forth an extra effort which resulted in poor singing. G. says, one does not want to try too hard. "I did better to-day than last time and didn't try nearly so hard." On one day R. made an extra effort to surpass a previous record with the result of making a poorer one. In conclusion it may be said that most rapid progress in the start was made by observers who put forth the strongest effort, but that later in the series too much effort worked for inefficiency as well as efficiency.

Attention is an important mental factor. At first it is largely secondary and forced, later it is primary and rather involuntary. B. made rapid progress, and it was evident that her attention was a main factor in it. She thinks efficiency is the result of attention more than any other single factor. As the tests went on attention not only changed in itself, but varied its object or charge, or work. At first it had to do with the singing quite as much as the hearing. Afterwards it had to do for the most part with the hearing aspect, the singing being in charge of
habits, automatizations and kinaesthetic sensations. The poorest singer in the series was subject to mind wanderings, not only at the beginning of the series but at the close. The accompanying discrimination test was a check upon this. It is possible to sing without giving attention, but it is not possible to discriminate between tones. The attention wavers. All the observers said that the tones were more distinct in their difference at some times than at others. A. remarked that often they seemed to blur. C.H. found it difficult at times to discriminate at all between tones which on other occasions were easy. This was also the case with C.S. Certain fluctuations both in the hearing and singing tests, which it is not possible to treat scientifically, also combine with the above facts to enable it to be concluded, that attention waves were present to effect in some degree efficiency in singing. The fact that "reversals" and "duplication!" cluster, and that the illusion of the small interval varies also points in that direction. It may be concluded that attention is a prominent factor in overcoming the difficulties of singing, that at first it is forced and voluntary, afterwards primary and only half voluntary, that it gives over the care of singing to habit and gives itself to the hearing aspect as the practice continues, that it is not uniform, but fluctuates. Excellence varies as primary attention focuses itself upon hearing the tones. The observers felt that attention of the right kind was a big factor in their efficiency and gain.
Confidence comes as a result of practice. While the singer is in the stage of "trial and error" singing, it is lacking. It does not come until the standard tones become familiar, until his own voice becomes familiar, until certain familiar strains in the throat are taken as signs of correct or incorrect singing. A gain in confidence brings better singing. Along with it are closely associated strong, tonal attack, shortness of reproduction, holding of the tone at one pitch, and uniformity of intensity.

The question of imagery in singing and hearing is more difficult to discuss than most mental factors because the observer finds great difficulty in giving the experiment a true and full account of it. Imagery of this type is difficult to locate, to corner, to analyze and define.

The observers said they had not a great deal of imagery, this amount often increased as they began to thoroughly introspect. In general, it may be said that as the practice goes on, more and more imagery is in evidence. Acquisition of imagery is then an element of gain through practice. It is a gain because it aids and does not hinder the singer. The imagery of B. is mainly visual and is carried over from former training in piano. The higher of two tones makes a loop which rises upward, the lower a loop which falls downward. The distance between the extremities of the two loops depends upon the difference in pitch of the two tones; if the two tones have a large increment the distance is great.
if a small increment, it is small. She often threw out her reproductions on the ground that this distance in them did not correspond to the difference of the standard tones. Thus she was able to keep the standard tones in visual memory long enough to compare her singing with them. This visual imagery was her chief means of passing judgment upon her singing. It is easily seen that this type of imagery does not aid in imitating the standard as much as in singing the correct interval. It was easier for her to visualize when the low tone came before the higher one. H. had a small amount of imagery which was revealed by introspection. Her imagery of the first tone was greater than that of the second, partly because she gave it more attention. The interval was a constant element in her memory. When singing she lowered or raised the second tone an amount equal to this interval. She said there was bigger strain on the memory in singing than in hearing. She said; "I have not much of any image of the tunes from the tuning forks, but it is impossible to sing near the tone without them."

"The sound of the lower tuning fork seemed to be in the resonator, and to come louder to the left, while the other seemed farther away and not at the resonator but all through the room, and to come from the right." "When too small an interval was used, the two standards did not stand out as clearly as when an interval of 2.v.d. was used." She further says:"If I get a good image of the tone, the throat muscles seem to adjust themselves automatically. When I am told that I have sung too high or too low, I try to correct it when listening to the forks, making them seem higher or lower than before, rather than by just singing lower or higher."
N.W. had an auditory image which was merely a sound, and when she sang correctly she felt in her mind that she had. G.W. found herself using little imagery. She heard the tone in her head and felt it there. This is true of the unchanging standard more than of the variant. She had no feeling of muscle tension in the throat which is a very good clue in judging the correctness of the singing. The most successful singer M.R.T. gave evidence of having had considerable, and varied imagery. His imagery was visual and auditory with the addition of his kinesthetic sensations in the throat. From the visual side an interval appeared like a stair step. He held this image of the standards in mind and compared it with the image which he got of the sung tones. He said that when he sang very accurately he had a feeling of "congruity" in the throat. He was very keen in passing judgment upon his singing as compared with the other singers. This was not the case with those observers who did not have the kinesthetic sensations which seemed to be a very efficient means of judging the correctness of the reproduction. Kinesthetic sensations are better than auditory and visual images in judging the correctness of the reproduction from the standpoint of the average error.

All the observers are more or less subject to the illusions of the small interval. The smaller the interval, the greater was the tendency to misjudge it. This illusion was one factor in causing the observers to sing too big an interval, lack of control over the voice was the other factor. This illusion varied at different times for the different singers. N.W. said:
"The difference between the tones seemed greater sometimes than at other times." G.W. had the illusion of thinking the standard tones farther apart than the tones of reproduction even when the reverse was true. Beside the illusion of the small interval there was the illusion due to expectation. This means thinking one tone higher or lower than the other because expectation accentuated it making it seem that way. C.H. lowered or raised both tones at will. N. W. said: "Quite often there was a tendency to prolong the tones, making the high tone higher and the lower tone lower."

Interest is closely associated with many other factors. It depends upon the past experience of the individual, those having had musical training as a rule were more interested in the series than those who had not had such training. The overconfident lacked interest as their failures stared them in the face. The unassuming enlivened as their records showed good work. As attention and self control heightened, interest was enhanced. The closer the observer was in touch with his results, except in a very few cases where they discouraged him at times, the keener was his interest. Showing him his curve tended to spur him on to surpass the record of the previous day. Judging by the expression on the face, quickness of step, tone of conversation etc. on several occasions, three observers showed a lack of interest with the result of making poorer records. A lively interest aids singing.

It may be said in summarizing that imagery of a helpful nature is gained through practice, that singing and hearing aids in revealing imagery possessed before the test, that the kinaesthetic
sensations are more helpful in imitation of the standard than auditory or visual imagery, that lack of control means less efficiency in singing, that confidence comes through practice and is a sign of gain, that attention and interest are the important factors in overcoming difficulties and acquiring imagery and other aids, that effort may or may not aid in singing, that practice makes the memory of the tones easier by increasing the imagery, and that the small interval illusion and illusion of expectation are ever present and cannot be entirely eliminated.

C. Comparison of Singing and Hearing Ability.

1. Comparison of the methods of measurement.

The method used in determining the pitch discrimination threshold of hearing was that of least perceptible difference with constant stimuli, the method used in singing ability was that of the average error with constant stimuli. A comparison of these methods will put the results of this series in a fairer light. In both the stimuli were constant for any one test, the standards were the basis for computation, the tones were given in rapid succession, and the same range of forks were used, in other words, the observer was not asked to discriminate between forks of the 256 v.d. pitch, when his voice sang down on the 128 v.d. pitch. The same resonator was used in each method. Discrimination of pitch in hearing taxes the memory less than discrimination action in singing. In the former, the two tones are compared immediately and the judgment is instant, in the latter, an act of singing comes in between the hearing of the second tone and the singing of it, with the tendency for the image of the second tone to be more or less washed out, making comparison
difficult and fraught with a strain on the memory. The ob-
servers all say that there is a greater strain upon attention
in singing than in hearing. Another disadvantage for the average
error method and discrimination action is the confusion factor
of hearing one's own reproduction of the first standard before
the second is imitated. Reference in the sentence above was made
to the disturbing factor of action, the second sentence after it
speaks of the disturbing factor of hearing one's own voice and
mistaking it for the second standard. The voice is richer in
quality than the artificial tone of the tuning fork, is fresher
in the memory than the second standard tone, hence there is a
tendency to make the second tone a duplication of the first.
The illusion of the small interval partly counteracts this tendency.
Discriminative action is at another disadvantage or advantage, it
is hard to tell which, in that the voice is not entirely subject
to the control of the singer. It will not minutely obey his orders.
There is an area of noncontrol through which and in which the voice
oscillates with considerable freedom. No matter what the interval
between the standard tones is, this erratic characteristic of the
voice affects the average error and if the interest is small,
it affects the ability of the observer to sing the smallest possible
interval. As was hinted above, this report is not able to say
whether the area of noncontrol in singing is an advantage or a
disadvantage to the method of average error. It is easily seen
that in some trials the voice may sing by mere chance closer to the
standard than the distance measuring the pitch discrimination
threshold, in others the error may be several times as large in
vibration frequency as the threshold. Just how the distributions of the reproductions should occur along the line marking these two extremities in the case of an observer who can sing as well as he hears is not known to the writer. There are two ways of facing this problem. One is from the empirical standpoint, the other from the theoretical. The empirical viewpoint would say whether or not in such a case the average error should be equal, greater, or less than the threshold, by judging the relation of the singer's hearing and singing ability in the light of a norm established by many records showing just what the average error should be in the case of a normal singer who has a certain threshold. The theoretical view aims at establishing the relation of the average error and threshold by mathematical calculations which take into consideration abstractly, and removed from experience, all the elements that enter into the two methods of procedure. This the writer is not able to do, he sees somewhat the difficulty and necessity of doing it, but this task will be left undone until later. In a word, then, the present report will not attempt to say whether a certain observer sings as well or better or worse than he hears. It will set forth the results of the experimentation leaving the reader to decide that matter for himself.

2. Relation of the least perceptible and least producible interval in pitch. Can the voice sing as small an interval as the ear can hear, if not, is there much difference between the least perceptible and least producible difference in pitch? Do those with good ears sing the smallest differences? These questions can be answered by going to the curve number fifteen. There is a close relation between the least producible and least perceptible differ-
ence in pitch. The voice can sing almost as small a difference as the ear can hear but not quite. The average threshold for the ten singers is .8 v.d., the average difference sung in the three best tests, viewed from the stand-point of making a small interval, was 1.1 v.d., in the best test 1.0 v.d. Only one observer sang a smaller interval than his ear could hear. The one with the best ear sang the smallest interval. The one with the poorest ear sang the largest interval.

3. Relation of the threshold of hearing and average interval deviation. The relation of the pitch discrimination threshold and the average interval deviation is seen by looking at curve number sixteen. Up until the time of the approach to the approximate physiological limit in singing, the average interval deviation in all cases was larger than the threshold. There was also no close relation between the two. The two observers with a threshold of .6 v.d. had a larger deviation than those with thresholds of .7 v.d., 1.2 v.d., 1.4 v.d., and 1.5 v.d. The average threshold was .8 v.d., the average deviation was 2.3 v.d. or about three times as large. Comparing the average deviation for the three best tests after the limit was approached with the threshold shows the threshold in every case to have been as large or larger than the deviation. The average threshold was .8 v.d. the average deviation was .3 v.d. The average interval deviation was greatly decreased by practice. This curve reveals the fact that the man with a comparatively large deviation in the beginning had a small one at the close of the test. The best singer at the beginning of a series, comparatively speaking, was not always the best at the close.
4. Relation of the average error of reproduction and the least perceptible difference in pitch. By looking at curve number seventeen the relation of the average error to the threshold may be seen. The average error for the entire series is from two to three times as large as the average threshold. When the average error of the three best tests is taken and compared with the threshold, it is found that with four observers it is less, with one it is equal, and with five greater than the threshold. After the approximate physiological limit is reached the relation or correlation between the average error and threshold is quite close, before the limit is reached the relation is not close. In the first ten tests the average error is just three times as large as the average threshold. After the limit is reached the average error for the five best tests is practically the same as the average threshold. Without training the average error is greater than the threshold, with training they are about equal. The observer who had the smallest average error for any single test had the best ear.

5. Identical and non-identical elements in hearing and singing of pitch. Having treated the objective identical and non-identical elements in the comparison of the two methods, it remains to consider now the identical and non-identical elements in hearing and singing from the subjective point of view or that of what actually takes place in the mind of the observer. In each there are: a comparison of the tones by judging the direction of the second tones and by judging how much difference there is between them; variations in the ease of correct response, caused by attention waves, mind wanderings, fluctuation of interest, and slight fatigue; a subconscious muscle movement in the throat which is more intense in
singing than in hearing; illusions of the small interval; imagery.

There are certain elements which are present in singing, but not present in hearing. Voluntary muscle control is a big factor in singing. A great deal of the training through practice comes along this direction. At first the control is forced and awkward and gives the voice a good deal of play, resulting in a wide area of non-control. As practice is continued, the area of non-control is lessened, the voice wavers less, is less erratic, sings with better attack and more confidence. Imitation is a general word covering the entire ground of singing as done in this series. Pitch discrimination is one of judgment, is definite, being either yes or no; pitch production is an act of imitation, of muscular adjustment, is not definite but varies with different degrees of accuracy. Imitation depends to some extent upon the subconscious elements of automatic adjustment. The evidence that singing becomes more or less automatic was given earlier in this report. There is a tendency to hum the tones in preparation for their singing. This was done to a large extent with a couple of the best singers. M.R.T. said that depriving him of this privilege would put him at a great disadvantage. This humming gives one the tones in his own voice, gets the throat muscles in readiness to sing, causes certain feelings of throat strain which, if duplicated in the reproduction, gives the singer the assurance of having done well. The throat adjustment set up by this humming is apt to be more accurate than an adjustment made after the tones are drowned, for being made when the tones are sounded, it enables the singer to fall in with them, a slight discord being quickly noticed.
Distinct sensations of strain were reported. There was great
difficulty for the observers in describing them.

Singing small pitch differences is something more
than hearing them. If the singer has a good ear and sings poorly,
greatest gain is made by mastering the non-identical elements
which are: voluntary muscle control, imitation, automatization,
humming the tone, distinct sensations of strain which are of a
different quality than the kinaesthetic sensations in hearing.

6. Leniency of the ear in singing. The observers lacked ability
to pass correct judgment upon their own singing. The ear was
too lenient. M.R.T. who is best singer in the group, having a
pitch discrimination of .4 v.d., let such errors as 1.3 v.d.+, 1. v.d.+, 1.5 v.d.+, 1. 5 v.d.-, 1.2 v.d.-, pass by in a test in
which his average error on the low tone was .3 v.d., on the high
tone .4 v.d., the interval of reproduction being .7 v.d. In an­
other observation when he was singing an interval of .5 v.d. he
let pass his judgment tones with an error of 1.1 v.d.+, 1.8 v.d.-,
1.1 v.d.-, 1. v.d.-, 1.3 v.d.+, 2.5 v.d.+, respectively. In this
observation his average error was .6 v.d./M.T. is by far keener
than the average observer in detecting tones that erred greatly.
C.H. who has a fine ear and good voice control, when attempting to
sing an interval of .5 v.d., felt entirely satisfied with tones
having an error of 1.2 v.d.+, 1.7 v.d.+, 1.5 v.d.-, 1.9 v.d.-,
1.8 v.d.-, 1.5 v.d.+; Her average error in this test was 8 v.d.
on the low tone and .9 v.d. on the high tone. C.W. who has a
threshold of .6 v.d. failed to reject tones of one single test,
having an error of 1.4 v.d.+, 1.7. v.d.+, 1.3 v.d.-, 1.1 v.d.-,
1.8 v.d.-, 2. v.d.-, 1.9 v.d.-, respectively.
The explanation for this is as follows: First, the standard tone with which a comparison of reproduction tone should be made is dim; the observer has the standard tone in mind when the reproduction tone is begun but when it is finished, the standard tone gives way to the reproduced one which now comes to the front in consciousness. The main way then of telling how far the reproduction tone is off is by the feeling in the throat. This feeling or sense is not fine enough to be due for the observer’s passing the necessary judgment of whether or no the tone is correct, unless the misadjustment be a large one. Asking an observer to decide what he has sung in the scale of vibration frequency is about like asking him to tell what the vibration’s frequency is of any tuning fork which one may happen to strike, without another tuning fork of known v.d. sounding along beside it.

D. The Transfer of Training.

The training series proper ended in each individual case when the interval deviation and the average error and constant error told that the singer had reached his limit in singing the smallest possible interval. Of the seven observers who attempted to sing with an interval of .5 v.d. all but one were unable to sing it consistently. Each observer who attempted to sing the .5 v.d. interval had several tests before any conclusion was made as to his ability to sing the interval. If he sang the interval at least .4 v.d. too large, if the constant error and average error were inconsistently large as compared with previous limit singing, if reversals and duplications were in evidence, it was decided that he could not sing the interval.

2. Conditions favorable. A small interval of 1. v.d. for the
men and 2. v.d. for the women, standards for imitation within the
range of the singer and not too close to the standards of the training
series, are conditions favorable to transfer of training.
139 v.d. and 140 v.d. were chosen as the upper and lower standards
respectively in the case of C.S. and M.R.T. 264 v.d. and 266 v.d.
were the standards chosen in the case of A., C.H., C.W. and N.W.
The details of procedure were the same as in the training tests,
with the exception of this slight modification in interval and
change of standards. The results show that the practice gained
is almost entirely carried over. H. sang with an average error of
.8 v.d. which is the same as in the training tests when an interval
of 2. v.d. was used in the eleventh and twelfth tests. C.W. had
an average error of 1.2 v.d. which is .4 v.d. greater than her
average error in the training series in the last two tests, the
eleventh and twelfth, when an interval of 2 v.d. was used. N.W.
showed loss of .3 v.d., M.R.T. a slight gain and C.S. no loss or
gain, as compared respectively with their average error for the
last two tests sung in the training series when the interval of
2. v.d. was used by or after the tenth test. As the approximate
physiological limit is approached by the tenth test, it is fair to
conclude that the entire training gained in the training series
is carried over under the conditions mentioned.

for the men and 9. v.d. for the women, brings a disturbing factor
into the test series, for this interval in each case is larger
than the singers had been singing in the training series. 133 v.d.
and 139 v.d. were the standards chosen for C.S. and M.R.T.,
264 v.d. and 273 v.d. the ones chosen for C.H. and N.W.
As the interval in either case is larger than what the observers had been singing during the training series, we cannot compare their singing in these tests with singing done in the training series when a like interval was used. We shall compare it with the average singing done in the training series after the tenth test, regardless of the interval. In the case of C.S. there is a falling off of only .1 v.d., with M.R.T. a loss of .4 v.d., with H.W. there is no gain or falling off either, and with C.H. there is a falling off of .7 v.d. Allowance must be made here for the fact that during the latter part of the training series the smallness of the interval made the average error larger, when comparing the average error of the training and test series where the interval in the latter is large. It follows from the above data that a small interval is a favorable and a large interval an unfavorable condition for the transfer of training. Finally, under favorable conditions, the greater part of the skill gained through practice is transferable.

3. Analysis of the elements transferred. The elements in this transfer of training are: ability to make the voice to make the voice sing a small interval, ability to imitate the standards more or less correctly, ability to hold the standard tones in mind long enough to make them the basis of judging the correctness of the reproduced tones, ability to keep from imitating the first reproduction tone instead of the second standard tone when singing the second tone, ability to schematize or to center the attention upon the first tone and to sing the second tone so much below or above, according as the judgment measures off the distance, ability to keep the voice steady, to attack the tone strongly,
ability to use kinaesthetic sensations as a sign, ability to use auditory and visual imagery, ability to keep the voice from "trailing" either sharp or flat, ability to keep from substituting variation in intensity for change in pitch, and ability to sing with confidence.